ISSN 0377-9335

ENTOMON

Vol. 38 March 2013 No. 1

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ENTOMON

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Annual subscription for Institutions: Rs 3000/- (in India); US$ 300/- (out side India)
Annual subscription for Individuals: Rs 1000/- (in India); US$ 150/- (out side India)

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ENTOMON 38(1): 1-18 (2013)
Article No. ent. 38101

First record of the genus *Gaurax* Loew (Chloropidae: Oscinellinae: Botanobiini) from India with descriptions of six new species

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ABSTRACT: The Genus *Gaurax* Loew is recorded for the first time from India. Six new species, *amnoni*, *bimaculatus*, *indicus*, *ninani*, *shillongensis* and *tomentosus* and an unnamed species are described from India. A key to Indian species of *Gaurax* is also given. © 2013 Association for Advancement of Entomology

KEYWORDS: Chloropidae, *Gaurax*, six new and an unnamed species.

INTRODUCTION

Andersson (1977) proposed the *Gaurax* group of genera and placed *Cestoplectus* Lamb, *Gaurax* Loew, *Gampsocer*a Schiner and *Pseudogaurax* Malloch under the group which was later followed by Kanmyia (1983) and others. Nartshuk (1983, 1987) in her revisionary works on Chloropidae included 9 genera under the tribe Botanobiini when she erected the tribe. Apart from the four genera named above, she added five more namely, *Eugaurax* Malloch, *Hapleginella* Duda, *Leucochaeta* Becker, *Pselaphia* Becker and *Pterogaurax* Duda to the tribe. Of these nine genera, only four, *Cestoplectus* Lamb, *Gampsocera* Schiner, *Hapleginella* Duda and *Pseudogaurax* Malloch have been reported from India (Cherian, 2013).

Gaurax Loew is the largest genus of the tribe. It is distributed in all the Zoogeographical Regions. Becker (1911) reported many species of *Gaurax* from the Oriental Region, especially Taiwan (Formosa) to which were added a few more by Duda (1934) and others. Sabrosky (1977) included nineteen species from the Oriental Region, a few of which were later transferred to other genera but Kanmyia (1983) reported some more species from the Region. This genus has not so far been recorded from India. Six new species, besides an unnamed species, from India are described here. A key to species from India is also given.

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MATERIAL EXAMINED

The type specimens are retained in the collections of the Department of Zoology, University of Kerala, Trivandrum for the present and shall later be deposited in the National Zoological Collections, Western Ghats Research Centre, Zoological Survey of India, Kozhikode (Calicut), Kerala.

RESULTS AND DISCUSSION

Genus *Gaurax* Loew

1863. *Gaurax* Loew, *Berl. Ent. Ztschr*., **7**: 35 Type species: *Gaurax festivus* Loew. By monotypy.

1864. *Botanobia* Lioy, *Atti 1st. Veneto Sci.* (3) **9**: 1125. Type species: *Botanobia dubia* (Macquart) (=*Oscinis dubia* Macquart, 1835). By monotypy.

1914. *Neogaurax* Malloch, *Canad. Ent.,* **46**: 119. Type species: *Neogaurax montanus* (Coquillett) (=*Gaurax montanus* Coquillett, 1898). By original designation and monotypy. Syn. Sabrosky, 1941.

Diagnostic Characters:

Head higher and wider than long; frons often thickly pubescent or hairy; frontal triangle smooth and shiny, reaching from middle to rarely anterior margin of frons; face with or without short carina in upper part; gena linear to narrow, usually silvery tomentose; vibrissal corner rounded; parafacialia not developed; a*nt* 3 oval or reniform, much wider than long; arista slender with dense pubescence; eye very large, slightly to distinctly pubescent; *ovt* and *ivt* at times subequal; *pvt* and *oc* upright, cruciate; *orb* 5-8; *if* in a row along outer margin of frontal triangle; thorax black or yellow with black markings; scutum often with black maculae or dark stripes; pleura smooth and shiny with or without maculae; scutellum rounded, convex, black to yellow; thoracic bristles long and slender; *h* 1, *npl* 1+2, *pa* 1 and short *pa* 2 developed; *as* at times longer than scutellum, *ss* 1-2; wing hyaline or partly infuscated; second costal sector longer than the third; legs simple, partly darkened or wholly yellow; femoral organ absent; tibial organ distinct, oval; abdomen oval, wholly black to partly yellow, subshiny, tomentose with dark or rarely pale hairs; female cerci long and slender. Male genitalia: epandrium large, broad and rounded with a small orbicular dorsodistal opening; cerci bilobed, weakly developed, often long and produced ventrad; surstyli long with long hairs; hypandrium weakly developed, mostly of open type, without latero-distal bifurcation; gonites broadly attached to hypandrium, broad and elongate, without well defined suture between pre- and postgonites in most species.

Distribution: All the Zoogeographic Regions.

Remarks: *Gaurax* is closely related to *Gampsocera* Schiner. However, in the former *ant* 3 is

rounded or reniform, arista arises from dorsobasal part of *ant* 3, epandrium is broad and rounded with a small orbicular dorso-distal opening, cerci are separated and usually long and projecting, surstyli are of a complex nature with various projections and hypandrium, pregonites and postgonites are fused to form a complex structure. But in *Gampsocera* though the phallic complex is of the same rigid type as of *Gauraxi*, yet *ant* 3 is oblique with thickened, densely hairy, apically inserted arista, epandrium is flat and apically broad, surstyli are simple and there are only indistinct traces of cerci.

Gaurax is a very large and speciose genus known by ninety seven species from the world (Encyclopedia of Life, 2013) and is distributed in all the faunal regions. However, it has not been reported from India. 6 new and an unnamed species from India are described here. A key to Indian species is also given.

Key to species of *Gaurax* Loew from India:

1. Wing with marginal infuscation extending from base to ending of R2+3 or from R1 to R2+3……………………………………………………………………………..2

   Wing without such infuscation, either colourless or partly diffusely brown………………………………………………………………………………..3

2. Marginal infuscation of wing extends from R1 to ending of R2+3; wing deeply infuscated at sides of R4+5 along about two-thirds its length basally; discal cell greatly widening distally with greatly convex m-m cross-vein which bears a tuft of black hairs medially on either side; second posterior cell with a short, black spine in upper half submedially…………………………………………………..*Gaurax* sp.

   Anterior marginal infuscation of wing extends from base to ending of R2+3; wing without infuscation along sides of R4+5; discal cell and m-m cross-vein normally developed, the latter without black hairs; spine on second posterior cell absent ……………………………………………………………………*ninani* Cherian sp. n.

3. Occiput and *ant* 3 yellow; pleura black, only brownish yellow anteriorly; legs almost wholly yellow……………………………………………..*shillongensis* Cherian sp.n.

   Occiput partly or entirely dark brown to black, *ant* 3 at least partly infuscated; pleura entirely black or wholly yellow with black macula covering at least part of *anepm*; at least hind femora or hind tibiae partly dark brown……………………………………4

4. Face yellow; gena yellow or reddish brown; pleura yellow with black maculae at least on *anepm*; femora predominantly yellow, at most weakly infuscated dorsally and ventrally………………………………………………………………………..5

Face and gena deeply infuscated to brownish black; pleura almost entirely black to brownish black; femora predominantly black or partly infuscated……….................6

5. Gena yellow; frontal triangle and vertex margin yellow, its width in the middle half that of *ant* 3; scutum black with yellow sides and two large yellow maculae, one each in the area of 1*dc* which extends to scutellar margin…… *bimaculatus* Cherian sp. n.

Gena yellowish brown, its width in the middle about one fourth that of *ant* 3; frontal triangle and vertex margin entirely black; scutum dorsally wholly black…… …………………………………………………………..*indicus* Ambily sp. n.

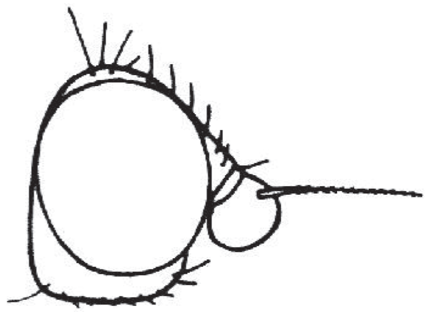
6. Frontal triangle, large, subshiny, reaching nearly anterior margin of frons and partly yellow in front of ocellar tubercle; eye with scattered fine pubescence; gena dull black; scutum subshiny, very weakly and finely tomentose; all femora predominantly brownish black……………………………………………….*amnoni* Cherian sp. n.

Frontal triangle dull, densely tomentose, not reaching beyond three-fourths length of frons, dull brownish black in front of ocellar tubercle and yellow at sides and anteriorly; eyes densely and conspicuously pubescent; gena dull brownish yellow, grey tomentose; femora only partly infuscated …… ………*tomentosus* Cherian sp. n.

***Gaurax shillongensis* Cherian sp. n.** (Figs.1-3)

Female: Head (Fig.1): Higher than long, length height and width ratio 9:11:14. Frons weakly narrowing anteriorly, a trifle widening at vertex, width at point of widening 0.53x that of head and 1.15x its own length, weakly tomentose, yellow with pale *fr* and ending with straight anterior margin; frontal triangle distinctly demarcated, shiny golden yellow, reaching a little behind anterior margin of frons and ending with nearly pointed apex. Face short, narrow, concave, yellow and finely tomentose; epistomal margin convex; facial carina triangular between bases of antennae and not extending beyond. Antennae erect, yellow; basal segments short; *ant* 3 reniform, 1.4x as wide as long; arista brown with short brown pubescence. Gena and postgena yellow, finely tomentose, the former narrowing anteriorly, width in the middle at most about 0.4x that of *ant* 3; vibrissal corner rounded, receding. Eye large with very fine, very short dense pubescence and nearly vertical long axis; occiput yellow. Proboscis short, brownish; palpi yellow with fine hairs. Head bristles yellow; *ovt* longer than *ivt*; *pv*t and *oc* cruciate, the latter shorter than ivt; *orb* 6, well developed, reclinate but posterior most one a trifle proclinate*; if* in a row of about 6, outside margin of frontal triangle.

Thorax: Scutum as long as wide and as wide as head, finely grey tomentose, subshiny yellowish brown but for darkened sides and three weakly demarcated blackish brown longitudinal bands commencing behind neck and reaching about two-thirds its length; posterior part of convex scutum also partly infuscated so that scutum appears darkened medially. Pleura dull brownish black, finely tomentose. Scutellum (Fig. 2) 0.7x as long as wide, yellowish brown but partly infuscated, disc convex bearing short brownish yellow hairs as on scutum. Thoracic bristles



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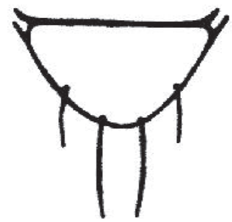

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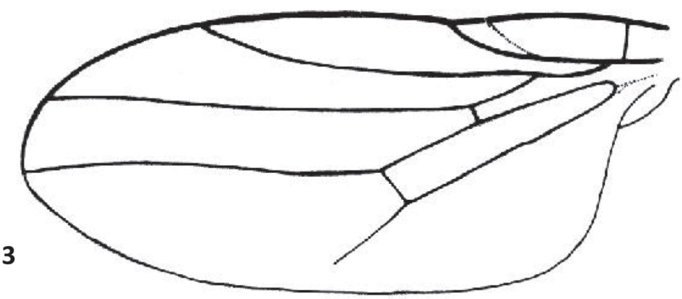

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Figs. 1-3: *Gaurax shillongensis* sp.n. 1. Head- profile; 2. Scutellum; 3. Wing

with slender *h* 1, 1+2 *npl*, *pa* 1, short *pa* 2 and normally developed 1 *dc*; *as* a little shorter than scutellum; *ss* 1 two-thirds as long as *as*; distance between bases of *as* and *ss* 1 more than that between bases of *as* bristles.

Wing (Fig. 3): 2.5x as long as wide, hyaline with pale brown veins; proportions of costal sectors 2 to 4 in the ratio 7:5:3; r-m cross-vein distad of middle of discal cell, opposite 0.6 of its length; terminal sectors of R4+5 and M1+2 not parallel, the former straight and the latter gradually becoming convex above medially and joining costa beyond apex of wing, anal area moderately developed. Haltere yellow but knob medially faintly infuscated.

Legs: Slender, of medium size, almost wholly yellow except for darkened hind coxa and brownish tinge anterio-dorsally and anterio-ventrally on hind femur; tibial organ oval with pale fine pubescence.

Abdomen: Suboval, brownish black with diffused faint yellow tinge on dorsum of some terga and more so on sterna, weakly tomentose with short pale hairs. Ovipositor broad basally and gradually narrows terminally, entirely brownish black.

Length: ♀ 1.8 mm; wing 1.88 mm.

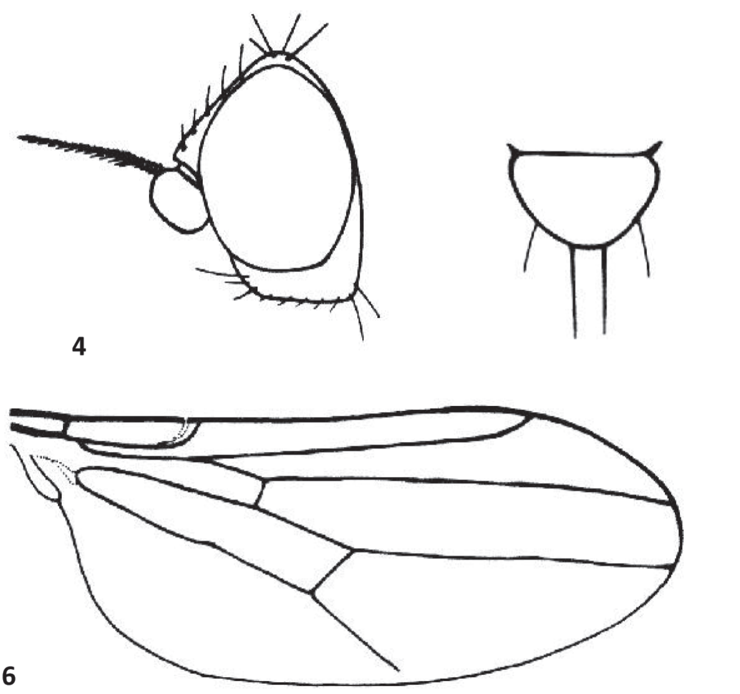
Holotype: ♀, India: Meghalaya: Shillong: Elephant Falls, 1350 m, 5 .vii.1979, Coll. P.T. Cherian.

Etymology: This species derives its name from its place of collection

Remarks: *G. shillongensis* comes close to *G. rubicundulus* Frey from the Philippines. However, in *shillongensis* second costal sector is only 1.4x as long as third sector, r-m cross vein is distad of middle of discal cell and terminal sectors of R4+5 and M1+2 are not parallel and the latter is convex above medially where as in *rubicundulus* second costal sector is about 2x as long as third sector, r-m cross vein joins discal cell somewhat in its middle and terminal sectors of R4+5 and M1+2 are parallel.

***Gaurax ninani* Cherian sp. n.** (Figs. 4-6)

Female: Head: (Fig. 4): Much higher than long, length height and width ratio11:13:16. Frons narrowing anteriorly, width at vertex a little less than half that of frons and subequal to its own length, dull brownish yellow, grey tomentose and with short pale *fr*; frontal triangle subshiny blackish brown with yellow sides, reaching middle of frons and ending with obtuse apex. Face



Figs. 4-6: *Gaurax ninani* sp.n. 4. Head- profile; 5. Scutellum; 6. Wing

narrow, deeply concave, dull brownish yellow; facial carina triangular between bases of antennae, low and reaches nearly middle of face whence it fades off. Basal antennal segments a little infuscated ; *ant* 3 yellow, reniform, 1.4x as wide as long; arista basally a little thickened with well developed pubescence. Gena in the middle about 0.4x as wide as *ant* 3, yellowish brown with dark tinge along oral margin; vibrissal corner receding, rounded; postgena narrow infuscated. Proboscis and palpi short and infuscated. Eye large, pubescence dense but longer than in *shillongensis,* with vertical long axis. Head bristles yellow; chaetotaxy similar to that of *shillongensis* but *orb* about 5, reclinate.

Thorax: A trifle narrower than head, dull brownish black and densely tomentose. Scutum 0.9x as long as wide with short, fairly dense pale hairs; pleura without maculae. Scutellum (Fig. 5) 1.33x as wide as long, rounded with weakly convex disc bearing hairs as on scutum. Thoracic bristles with *h* 1, 1+2 *npl*, 1 *pa*, 1 *dc* and hair-like *pa* 2; *as* shorter than scutellum; *ss* 1 about two-thirds as long as *as*; distance between bases of *as* much less than that between *as* and *ss*1.

Wing (Fig. 6): 2.8x as long as wide; proportions of costal sectors 2 to 4 in the ratio 22:11:5; r-m cross-vein far distad of middle of discal cell opposite about 0.65 of its length; m-m cross-vein strongly oblique; terminal sectors of R4+5 and M1+2 early parallel but weakly convergent distally, the latter joining costa a trifle beyond apex of wing; costal and subcostal cells entirely, basal radial cell partly and MG3 and MG4 along their borders infuscated. Haltere yellow.

Legs: Coxae partly darkened; fore and mid femora yellow but one-third their lengths distally blackish brown; hind femora and fore and hind tibiae predominantly darkened; mid tibia partly dark brown and partly yellow; basal tarsi of all legs yellow and distal segments infuscated.

Abdomen: Oval, brownish black with distal segments partly yellow, wholly with short pale hairs. Ovipositor short with a few hairs.

Length:♀ 1.87mm; wing 1.84mm.

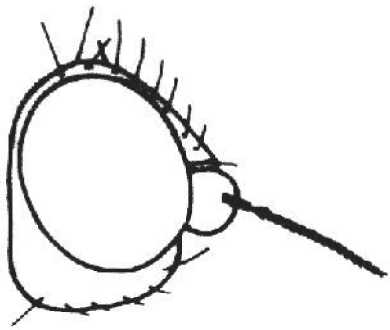
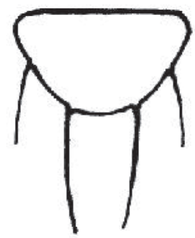
Holotype:♀, India: Tripura: Maichera, 27.ix.1977, Coll. T.N. Ninan.

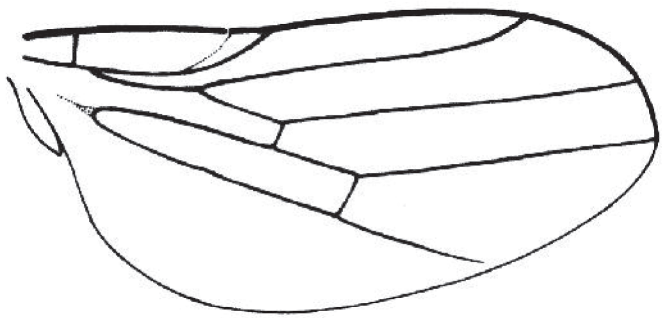
Etymology: This species is named after the collector of the specimen.

Remarks: *G. ninani* shows affinities to *shillongensis* but differs in frontal triangle reaching only middle of frons and in having partly infuscated wings and partly darkened legs where as in the latter species frontal triangle reaches nearly anterior margin of frons, wings are not infuscated and legs are almost wholly yellow.

Gaurax amnoni Cherian sp. n. (Figs. 7-9)

Male: Head (Fig. 7): Only a little higher than long, length height and width ratio

7  8 

9 

Figs. 7-9: *Gaurax amnoni* sp.n. 7. Head- profile; 8. Scutellum; 9. Wing

6:7:11. Frons gradually widening posteriorly, width at vertex 0.55x that of head and about 1.4x its own length, dull dark brown but for blackened vertex margin and brownish yellow tinge at sides of lateral margins of frontal triangle, with a few short *fr*; frontal triangle clearly demarcated, more than two-thirds as wide as frons at vertex, shiny brownish yellow except for black ocellar tubercle, ventral margin and posterior-lateral sides, reaching a little behind anterior margin and ending with nearly pointed apex. Face narrow, higher than wide, dark tomentose, dull brownish black; epistomal margin convex medially and projecting forwards; facial carina triangular between bases of antennae and not extending beyond. Basal antennal segments darkened; *ant* 3 reniform, 1.4x as wide as long, brownish yellow but darkened along anterio-distal margin and the area around; arista a little thickened at base, of medium length, dark brown with concolorous pubescence. Gena narrowing anteriorly , width in the middle about half that of *ant* 3, dull black, silvery tomentose; vibrissal corner rounded, receding; postgena concolourous with gena. Occiput dull black. Proboscis and palpi dull black, the former shortened. Eye large, oval with vertical long axis and very scattered pubescence. Head bristles brownish black, chaetotaxy similar to that of *ninani.*

Thorax: Scutum a little narrower than head, nearly as long as wide, subshiny black, weakly

tomentose with short dark pubescence. Pleura dull black, dark tomentose, without maculae. Scutellum (Fig. 8) 0.7x as long as wide, rather narrowly rounded with weakly convex disc which is concolourous with and tomentose and pubescent like scutum. Thoracic bristles black with 1 *h*, 1+2 npl, 1 *dc*, *pa* 1 and short *pa* 2 bristles; *as* a little longer than scutellum, fairly widely separated at base; *ss*1 two-thirds as long as *as*; distance between bases of *as* and that between bases of *as* and *ss*1 subequal; all scutellar bristles borne on fine warts.

Wing (Fig. 9): Hyaline with pale brown veins; costal sectors 2 to 4 in the ratio 8:5:3; r-m cross-vein distad of middle of discal cell opposite 0.62 of its length; terminal sectors of R4+5 and M1+2 subparallel; anal area moderately developed. Halteres infuscated.

Legs: Coxae black; hind femur entirely, but for faint yellow tinge at distal end, brownish black; mid-femur predominantly and fore-femur mostly blackish brown except for partly diffused faint brownish yellow tinge; tibiae mostly yellow with faint brown tinge especially on hind tibia; tarsi yellow; tibial organ distinct.

Abdomen: Subshiny brownish black with a few short hairs.

Length: ♂: 2. 0 mm; wing: 1.9 mm

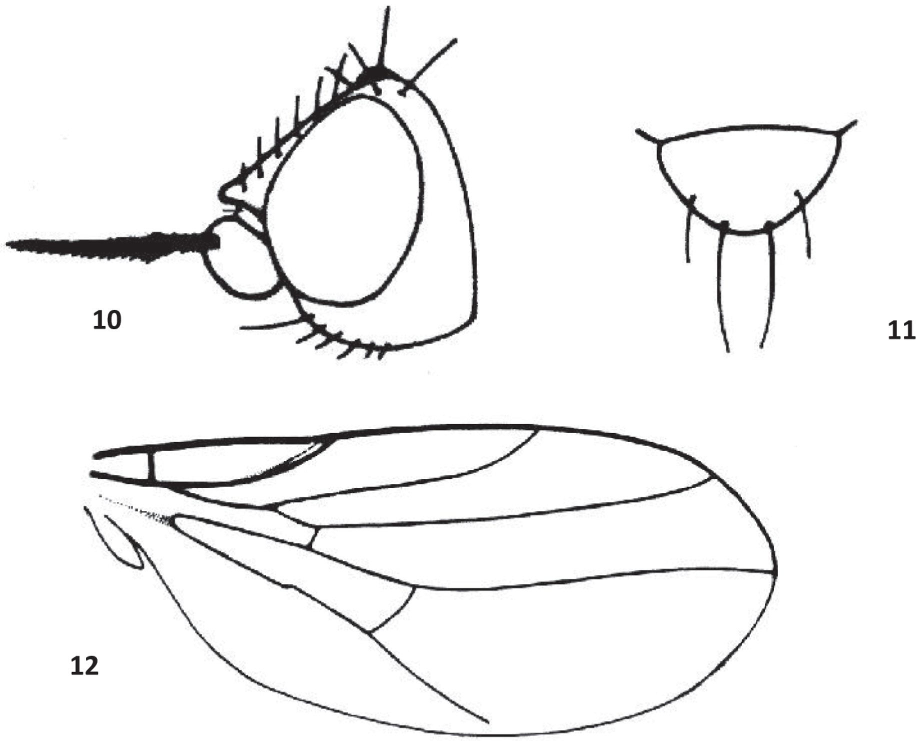
Holotype: ♂, India, Meghalaya; Nangpo, 535 m, 23.iv.1980, Coll. Amnon Freidberg.

Etymology: The species is named in honour of Dr. Amnon Freidberg, Tel Aviv University, Israel, who had collected and donated the specimen for study.

Remarks: *G. amnoni* keys near *shillongensis* but in the former occiput is black, *ant* 3 is partly infuscated, pleura is entirely black, frontal triangle is black at vertex margin and femora are predominantly blackish brown whereas in *shillongensis* occiput and *ant* 3 are yellow, pleura is brownish yellow anteriorly, frontal triangle is almost entirely yellow and legs are almost wholly yellow.

***Gaurax tomentosus* Cherian sp. n.** (Figs.10-12)

Male: Head (Fig. 10): As long as high, length, height and width ratio 11:11:16; frons slightly narrowing anteriorly, widening at vertex, width at point of widening half that of head and 1.1x its own length, brownish yellow, finely grey tomentose with short dark finely punctate hairs and ending with slightly convex anterior margin; frontal triangle subshiny, brownish black but for yellow sides and anterior part, its width at vertex about two thirds that of frons, finely grey tomentose, reaching almost two-thirds length of frons and ending with narrowly obtuse apex. Face deeply concave, dull brownish yellow with dark tinge in some areas; facial carina low, triangular between antennae and not extending much beyond. Antennae erect, basal segments brownish yellow; *ant* 3 reniform, 1.4x as wide as long, yellow but deeply infuscated along dorsodistal margin; arista brownish black with dense, conspicuous, concolourous slender hairs. Gena dull brownish yellow with dark tinge along oral margin, narrowing anteriorly,



Figs. 10-12: *Gaurax tomentosus* sp. n. 10. Head- profile; 11. Scutellum; 12. Wing

width in the middle about one-third that of *ant* 3; vibrissal corner receding, not reaching anterior margin of eye; oral vibrissae well developed; oral setae about 7-8, slender but very conspicuous; postgena well developed, darkened posteriorly and concolourous with gena anteriorly. Eye large, densely and conspicuously pubescent with nearly vertical axis. Proboscis and palpi darkened with fine hairs. Head bristles well developed, brownish black; vertex margin with a row of dark hairs; *ovt* and cruciate *ivt* subequal, *ivt* a little shorter than *ovt* and subequal to longest *orb*; *oc* about half as long as *pvt*, reclinate; *orb* 6 as in *G. amnoni; if* in a row about 5-6 along outside margin of frontal triangle, shorter than *orb*.

Thorax: Almost wholly brownish black. Scutum a little narrower than head, nearly as long as wide, dull brownish black, densely grey tomentose but anterior part partly appears having golden yellow tinge in certain angles of illumination. Scutellum (Fig. 11) about 1.5x as wide as long with convex disc which is concolourous with and pubescent like scutum. Pleura concolourous with scutum except for subshiny propleuron and lower and posterior parts which are with light yellow tinge. Thoracic bristles black with 1 *h*, 1+2 *npl*, 1 *dc*, *pa* 1 and *pa* 2, bristles as in *ninani*; *as* 1.2x as long as scutellum, widely separated at base; *ss* 1, 0.6x as long as *as;* distance between bases of *as* and *ss* 1 subequal.

Wing: (Fig. 12): 2.25x as long as wide, hyaline with pale brown veins; proportions of costal sectors 2-4 in the ratio 30:22:13, r-m cross-vein distad of middle of discal cell, opposite 0.56 of its length; terminal sectors of R4+5 and M1+2 gradually diverging distally, the latter weakly sinuate and slightly convex above medially; m-m cross-vein oblique; anal area a little receding. Haltere yellow but partly infuscated.

Legs: Predominantly yellow with diffused dark tinge especially on fore and hind femora and some areas of tibiae, tibial organ developed.

Abdomen: Suboval, subshiny brownish black but for faint yellow tinge medially on dorsum of basal segments, weakly tomentose with fairly dense well developed black hairs especially on distal segments.

Length: ♂ 1.46 mm; wing 1.56 mm.

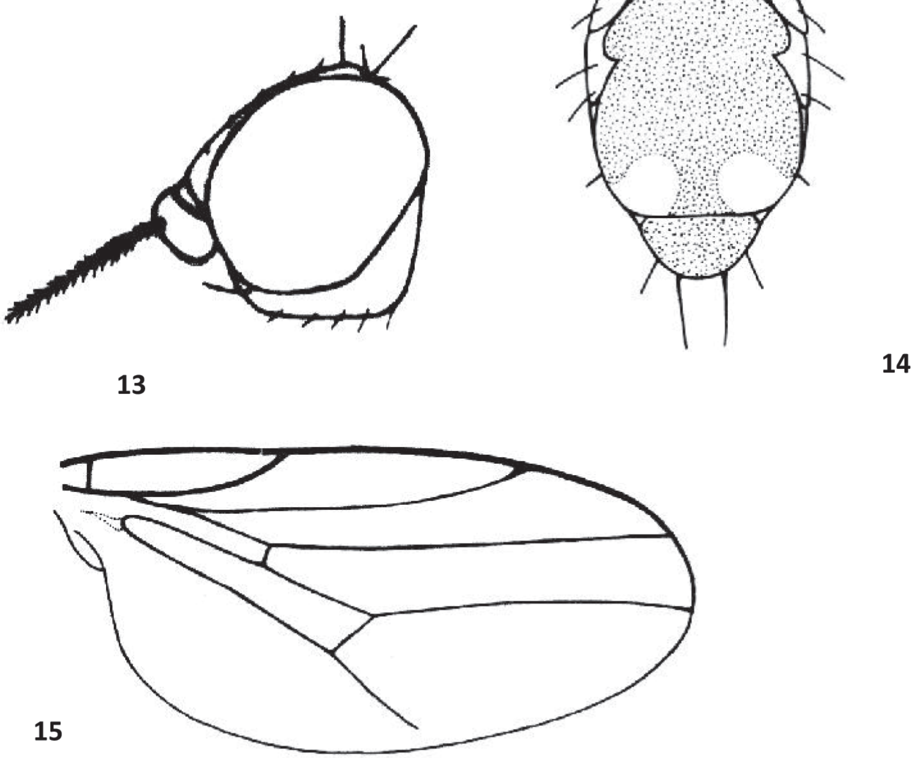
Holotype: ♂, India: Kerala: Ernakulam Dt., Vazhakulam, 14.viii.2011, Coll: E.G. Ambily

Etymology: ***G.** tomentosus* derives its name from its densely tomentose frontal triangle.

Remarks: *G. tomentosus* shows affinities to *G. amnoni* but in the former frontal triangle is dull, densely tomentose and reaches not beyond three-fourths length of frons, eyes are densely and conspicuously pubescent, gena is dull brownish yellow, scutum is dull and densely grey tomentose, femora are only partly infuscated and *ss* 2 is present. But in *G. amnoni* frontal triangle reaches nearly anterior margin of frons, eye is with scattered fine pubescence, gena is dull black, scutum is subshiny and very weakly and finely tomentose, femora are predominantly brownish black and *ss* 2 is absent.

***Gaurax bimaculatus* Cherian sp. n.** (Figs. 13-15)

Male, *female***:** Head (Fig. 13): Length height and width ratio 6:7:9. Frons nearly parallel-sided but widening at vertex, width at point of widening 0.55x that of head and 0.9x its own length, finely pale tomentose, yellow with fine concolourous *fr*; frontal triangle clearly demarcated, large, glabrous, about three-fourths length of frons and ending with narrowly obtuse apex, concolourous with frons except for brown tinge in front and sides of deeply infuscated ocellar tubercle. Face deeply concave, finely grey tomentose, yellow; epistomal margin convex, and projecting medially, with dark rim; facial carina weak, triangular between bases of antennae and not extending beyond. Basal antennal segments yellow; *ant* 3 reniform 1.4x as wide as long, yellow but darkened in upper half, basally and along dorso-distal margin; arista basally slightly thickened, dark brown with short, concolourous pubescence; gena narrowing anteriorly, width in the middle about half that of *ant* 3, pale tomentose, yellow; vibrissal corner rounded, a little receding; postgena confined to lower half of head posteriorly, concolourous with gena. Eye large, almost naked; occiput darkened below yellow vertex margin. Proboscis short, darkened; palpi yellowish brown. Head bristles yellow; *ovt, ivt, pvt* and *oc* as in *G. amnoni; orb* about 6; *if* as in *G. amnoni.*



Figs. 13-15: *Gaurax bimaculatus* sp.n. 13. Head- profile; 14. Scutellum; 15. Wing

Thorax: Scutum 1.15x as long as wide, shiny, weakly tomentose with convex black disc which is yellow at sides and with 2 large yellow maculae posteriorly, each on either side in the area of 1*dc* and extending to posterior margin of scutum with a median black area in the form of a black band, in one specimen maculae are larger and longer; humeral callus well developed, yellow with brown tinge medially, especially in one specimen. Pleura subshiny yellow with nearly oval black maculae on *anepm* and brownish macula on *kepst.* Scutellum: (Fig. 14) broadly rounded, 1.35x as wide as long, with weakly convex, black, finely tomentose disc; thoracic hairs yellow and thoracic bristles dark brown; *h*1 short; *npl* 1+2, subequal; *pa* 1 and 1 *dc* subequal and equal to *npl*; *pa* 2 hair-like; *as* a little longer than scutellum; *ss* 1 two-thirds as long as *as*; distance between bases of *as* and that between *as* and *ss* 1 subequal.

Wing (Fig. 15): 2.3x as long as wide, hyaline with brown costa and brownish yellow veins; proportions of costal sectors 2 to 4 in the ratio 18:12:7; r-m cross-veins joining at four-sevenths length of discal cell from base; terminal sectors of R4+5 and M1+2 subparallel, the former slightly diverging distally before joining costa, the latter joining costa at apex of wing. Haltere yellow.

Legs: Predominantly yellow but hind tibia along one-third its length basally, especially in the holotype, darkened; mid and hind femora with deep brownish tinge along anterio-dorsal and posterior-ventral surfaces; tibial organ developed; femoral organ absent.

Abdomen: Short, much narrower than thorax, female cerci long, slender, yellow. Male genitalia partly damaged.

Length: Male 1.72 mm; wing 1.84 mm.

Female: 1.88 mm; wing 2 mm.

Holotype: ♀ : Tamil Nadu : Periyar Dist., Gathisal, 5.i.1990, Coll. P.T. Cherian

Paratype: ♂ : Tamil Nadu : Coimbatore Dist., Kunjapanai, 1200 m, 9.ii.1992, Coll. C. Radhakrishnan.

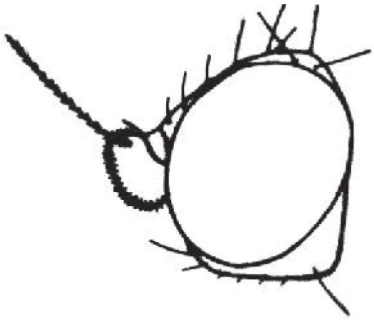
Etymology: The species derives its name from the two yellow maculae on scutum.

Remarks: *Gaurax bimaculatus* shows affinities to *amnoni* but in the former gena and face are yellow, scutum is with two large yellow maculae posteriorly, sides of scutum, much of pleura, coxae and much of femora are yellow and abdomen is short and narrow. But in *amnoni* gena, face and thorax are entirely black, coxae wholly and femora predominantly are black and abdomen is normally developed.

***Gaurax indicus* Ambily sp. n.** (Figs. 16-18)

Female: Head (Fig. 16) Length, height and width ratio 15:19:26. Frons slightly widening at vertex, width at point of widening subequal to its own length and two-thirds width of head, sunken in middle, yellow with slight reddish tinge and a few dark brown *fr*. Frontal triangle large, shiny brownish black, reaching about three-fourths length of frons and ending with narrowly obtuse apex. Face concave medially, weakly tomentose, yellow with narrow brownish black epistomal margin which is with sublinear dark brown horizontal marginal band. Gena yellowish brown, narrowing anteriorly, width in the middle one-fourth that of *ant*3; vibrissal corner receding; postgena reduced, concolourous with gena. Basal antennal segments darkened, *ant* 2 with conspicuous dorsal spine, *ant* 3 reniform, 1.4x as wide as long, grey tomentose, brownish yellow in lower half and deeply infuscated in upper half and along dorso-distal margin; arista long and slender, blackish brown with fairly dense concolourous hairs; occiput shiny brownish black. Palpi and proboscis yellow. Eye large with nearly vertical long axis and fine, very scattered pubescence. Head bristles slender, dark brown, almost similar to that in *biocellatus* but *orb* 5 of which anterior most two are short and the rest nearly subequal.

Thorax: Scutum about 0.8x as long as wide, shiny black but for partly yellow humeral callus and sides upto transverse suture, disc weakly convex with slender fairly dense, pale yellow



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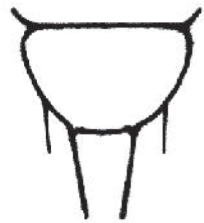

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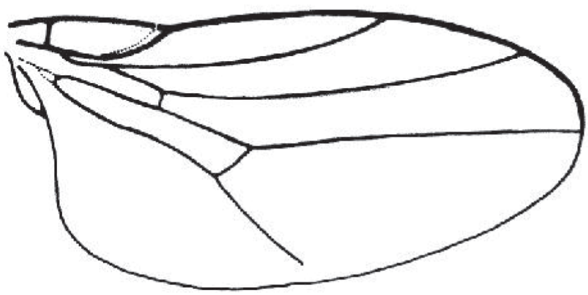

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Figs. 16-18: *Gaurax indicus* sp.n. 16. Head- profile; 17. Scutellum; 18. Wing

hairs. Pleura yellow with narrow longitudinal brownish black band on *anepst*, part of *anepm* and much of the area of meron. Scutellum (Fig. 17) about 1.2x as wide as long, rounded distally with weakly convex disc which is concolourous with and pubescent like scutum; thoracic bristles dark brown, bristles on scutum similar to those of *biocellatus*; *as* a little shorter than scutellum; *ss* 1 about 0.4x as long as *as*; distance between bases of *as* and *ss* 1 nearly subequal.

Wing (Fig. 18): 2.2x as long as wide, hyaline with pale brown veins; proportions of costal sectors 2-4 as 12:7:5; *r-m* cross-vein distad of middle of discal cell, opposite 0.57 of its length; *m-m* cross-vein oblique; terminal sectors of R4+5 gradually becoming concave above along its entire length, turning upwards before joining costa and that of M1+2 nearly straight so that R4+5 is divergent from M 1+2 distally. Anal area of wing normally developed; haltere pale yellow.

Legs: Slender, predominantly pale yellow but mid femora weakly and hind femora partly with diffused dark brown tinge; tibial organ developed.

Abdomen: Short but medially nearly as broad as thorax, shiny brownish black but for broadly v-shaped yellow area covering broadly the first and narrowly in the middle of second basal

segments; hairs on abdomen slender, dark brown; female ovipositor very slender, brownish black.

Length: ♀ 1.4 mm; wing 1.3 mm.

Holotype: ♀, Kerala: Trivandrum Dist; Pangapara, 25 m, 24.ix.2011, Coll. E.G. Ambily.

Etymology: The species derives its name from the name of the country of its distribution.

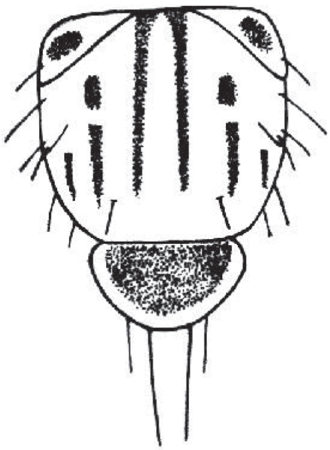
Remarks: *G. indicus* keys near *bimaculatus* but in the former frontal triangle and vertex margin are black to brownish black, gena is yellowish brown and its width in middle is only one-forth that of *ant* 3 and scutum dorsally is wholly black whereas in *bimaculatus* frontal triangle and vertex margin are yellow, gena is yellow and is half as wide as *ant* 3 and scutum is with two large yellow maculae posteriorly, one each in the area of 1*dc*.

Gaurax sp. Fig. (19-20)

A specimen, the head of which is lost, apparently appears to belong to *Gaurax*. It is not named but described here because of some unique characters of its wing not seen in other species of Chloropidae.

Thorax: Scutum about 1.2x as wide as long, densely and conspicuously grey tomentose, brownish yellow with four posteriorly separated brownish black longitudinal stripes of which two median ones commence at neck and are abbreviated posteriorly at level of 1*dc* and each lateral one begins from level of lower margin of humeral callus, is broadly interrupted at transverse suture and ends posteriorly a little below termination of middle ones; apart from four stripes, two each on each side of scutum, there is a short narrow, less distinct dark stripe laterally, commencing from humeral callus and fading off behind base of *pa* 2; scutum convex anteriorly and a little flattened medially and posteriorly, wholly with dense well developed pale hairs; humeral callus well developed, distinctly marked off from scutum, brownish yellow but infuscated medially. Pleura subshiny, almost polished reddish brown but for partly tomentose infuscated *anepst* which is with a shiny black macula along its lower posterior margin. Scutellum (Fig. 19) rounded, 1.2x as wide as long, weakly convex, dark brown in upper half and brownish yellow in lower half and along sides, tomentose and pubescent like scutum. Thoracic bristles well developed, brownish black; *h* 1 shorter than anterior *npl*; *npl* 1+2 anterior one a little longer and posterior 2 subequal; *pa* 1 and 1 *dc* subequal to *npl*; *pa* 2 hair-like; *as* 1.2x as long as scutellum; widely separated at base; *ss* 1 about 0.6x as long as *as* but slender, distance between bases of *ss* 1 and *as* less than that between *as*.

Wing (Fig. 20): Only 1.9x as long as wide, widened midially than at anal area; proportions of costal sectors 2 to 4 in the ratio 16:11:6; r-m cross-vein in the middle of discal cell; terminal sectors of R4+5 and M1+2 convex above submedially and slightly diverging distally; M1+2 convex above submedially and slightly diverging distally; M3+4 medially concave below and



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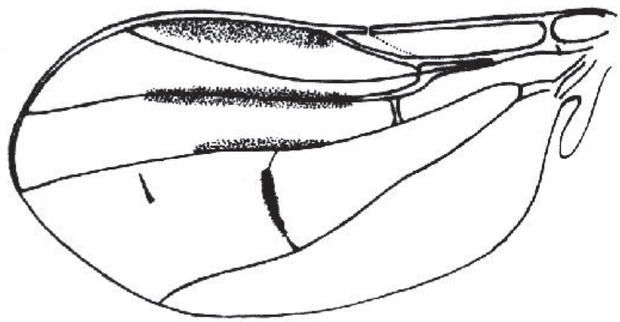

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Figs. 19-20: *Gaurax* sp. 7. Scutellum; 8. Wing

a little convex above distally before joining costal margin; discal cell greatly broadened distally unlike in normal species of *Gaurax*; m-m cross vein greatly convex outwards medially and is with a tuft of prominent black hairs medially above and below; second posterior cell with a short black spine in upper half submedially; marginal infuscation of wing extends from R1 to R2+3 and the area below; wing deeply infuscated at sides of terminal sector of R4+5 along about two-thirds its length basally. Vein R1 with a very short incomplete cross- vein like extension at the bifurcation of R2+3 and R4+5, almost connecting the veins on in some species like *Dasyopa scutellata* (von Roser). Haltere yellow with partly brown stalk.

Legs: Yellow but for diffused brown patches of femora and tibiae; hind femora a little swollen.

Abdomen much narrower than thorax, dull brownish black except for yellow colouration submedially on terga of basal segments; hairs on abdomen short, yellow, fairly dense. Male genitalia fairly large, bends and turns forwards, with conspicuous hairs.

Specimen Studied: ♂ (head fallen off) India, Kerala: Trivandrum Dist., Kariavattom, 25m; 13.xii.2005, Coll. P.T. Cherian.

Remarks: This species (the head of the specimen is lost) appears to belong to *Gaurax* in respect of some body characters, especially of thorax. However it differs from typical species of *Gaurax* in the development of its wing. Its wing is a trifle less than 2x as long as wide, discal cell is greatly widened distally, m-m cross vein is convex above medially and is with a tuft of black hairs above and below medially, M4+5 joins costal margin and there in a short black spine in upper half submedially on second posterior cell. Such a combination of characters is

not found in other species of *Gaurax* or other Chloropid flies. This species may belong to an entirely different genus but cannot be stated with exactitude without studying the characters of its head.

Abbreviations

anepm – anepimeron; *anepst* – anepisternum; *ant* 1 - first antennal segment; *ant* 2 - second antennal segment; *ant* 3 - third antennal segment; *as* - apical scutellar bristle; 1 *dc* - first dorsocentral bristle; *fr* - frontal hair; *h* -humeral bristle; *if* – inter frontal bristle; *ivt* - inner vertical bristle; *kepst* – katepisternum; *npl* -notopleural bristle; *oc* - ocellar bristle; *orb* – fronto-orbital bristle; *ovt* - outer vertical bristle; *pa* -postalar bristle; *pvt* - postvertical bristle; *ss* - subapical scutellar bristle; R2+3- radius 2+3; R4+5- radius 4+5; M1+2- median vein 1+2. MG3- 3rd costal segment; MG4- 4th costal segment.

ACKNOWLEDGEMENTS

We are grateful to the Science & Engineering Research Board, Department of Science and Technology, Govt. of India for financial support and to Dr. G. Prasad, Head of the Department of Zoology, University of Kerala for facilities.

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(Received 19.06.2014; accepted 22.08.2014)

ENTOMON 38(1): 19-26 (2013)
Article No. ent. 38102

Identity and biology of the Blue Mormon, *Papilio polymnestor* Cramer (Lepidoptera: Papilionidae)

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ABSTRACT: Investigations were made on the morphology and biology of the Blue Mormon, *Papilio polymnestor* Cramer. Morphological details pertaining to the wing venation and external genitalia along with the details of immature and adult stages are given. The life history was completed in 40-46 days. *Euodia ridleyi* (family Rutaceae) was recorded as a new larval host plant of this butterfly.
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KEYWORDS: Blue Mormon, *Papilio polymnestor*, External genitalia, *Euodia ridleyi*.

INTRODUCTION

Papilio polymnestor Cramer (Blue Mormon) is a tailless black swallowtail butterfly measuring 120- 150 mm in wing span. The hind wings have a glistening bluish tinge. It is closely similar to the Sri Lankan form *P. polymnestor parinda* Moore except for the buff coloured female form of the latter. It is widely distributed in India being recorded from Jharkhand, Madhya Pradesh, S. Gujarat, W. Bengal, Kerala, Karnataka, Goa, Tamil Nadu, Maharashtra and Sikkim (Talbot, 1939; Konte, 2000). The larvae feed mainly on Rutaceae plants and it has been reported as a minor pest of cultivated citrus plants although no severe outbreak has been so far reported from India. Recently, an investigation has been made on the systematics of the Swallowtail butterflies of Kerala. Information generated on the taxonomy and biology of *P. polymnstor* butterfly is presented in this paper.

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MATERIALS AND METHOD

Morphological studies were carried out using samples collected from different locations in Kerala during 2010-2012. The areas covered included Nilambur (11°17' 58" N 76°15' 03" E), Peechi (10° 31' N, 76° 24' E), Vazhani (10° 36.75' N 76° 24.42' E), Athirappilly (10° 17' 19" N, 76° 32' 54" E), Vazhachal (10° 14' N, 76° 25' E) and Thenmala (8°57' 0" N and 77°4' 0" E). Microscopic slide mounts of body parts were prepared using standard methods (Mathew and Ramadas Menon, 1985). For preparing slide mounts of external genitalia, the parts were dissected out from samples treated with 10 % KOH. It was then stained with Acid Fuschin (in acetic acid) and cleared in Carbol- Xylol (solution of Carbolic Acid and Xylene in 2: 3 ratio) and then mounted in Canada balsam.

The biology was studied by rearing the field collected eggs in small glass jars (16 x 10 cm in size) covered with a clean, dry cloth and securely fastened with a rubber band. The containers were kept moist by placing a small piece of moist absorbent tissue. Frass and excreta accumulated in the container were removed daily and the larvae were provided with fresh leaves of citrus. The duration of the larval instars was recorded based on observations of the moulted shells of the caterpillar's head that remains inside the container after moulting. The size of the caterpillar (length and breadth), mode of feeding, pupation and emergence were also recorded. Towards the end of the final instar, when the larva shows signs of pupation, a dry twig was placed within the container so as to provide anchorage to the pupa.

RESULTS AND DISCUSSION

Taxonomy: *Papilio polymnestor* Cramer (Blue Mormon)

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Material in collection: 3♂& 3♀&., 25.xi.10, Peechi; 14.x.11, Thenmala; 12.ix.11, Nilambur.

Wing span: 120.30 (± 13.15) mm.

Distribution: India (Peninsular and Central India), Sri Lanka and Myanmar: In India, specifically recorded from Jharkhand, Madhya Pradesh, S. Gujarat, W. Bengal, Kerala, Karnataka, Goa, Tamil Nadu, Maharashtra and Sikkim. During the present study, it has been recorded from Nilambur, Nadukani Ghat, Aralam, Thirunelli, Thrissur, Palakkad, Peechi, Vazhani, Athirappilly, Vazhachal, Valppara, Chinmoni and Thenmala.

Status: Common (Gaonkar, 1996).

Hosts: *Atalantia racemosa, Atalantia wightii, Glycosmis arborea, G. pentaphylla, Paramigyna monophylla, Citrus grandis, C. limona, C, documana, C. maxima,* cultivated limes (Rutaceae) and *Garcinia xanthochymus* (Clusiaceae). *Euodia ridleyi* was recorded as a new host plant at Peechi.

Description: Blue Mormon the second largest of the Southern Indian butterflies, has an expanse of 120.30 (± 13.15) mm. Upperside of forewing is black, with a pale blue discal band which narrowing towards the apex. This pale blue band is traversed by black transverse stripes along the veins. The underside is opaque black with an elongate dark red spot at the base of the cell in the forewing. The one-third of the upper side of the hind wing is black and the remaining part is pale with a row of black discal spots, a similar row of black sub-marginal spots and a row of marginal black spots. Some of the sub-marginal spots coalesce with the marginal spots. The hind wings are tail-less. The underside of the hind wings have five irregular small patches of reddish at the base. The head, thorax and abdomen are uniformly blackish brown.

Wing venation: There are 12 veins in the forewing with a large, closed, discal cell with several veins radiating from it. Among the 12 veins, the first and the last are arising from the base and the remaining from the discal cell. On the forewing, vein 12 (Subcosta; Sc) coalesces with the 11^{th} (R5) vein. All the five branches of the Radial veins (Veins 11 to 7; R1-R5) are present. Veins 6 to 4 form the Median veins (M1 to M3). Veins 3-2 are the Cubital veins, Cu1a and Cu1b and the last vein is the Anal vein, which has two branches *viz.,* 1A and 2A. The second Anal vein is short and third Anal vein is totally absent.

In the hind wing, the first radial vein is fused with Subcosta (vein 8) forming Sc + R1 are fused). The Radius (7^{th} vein) which is undivided and is termed Radial sector. The Median vein (M) has three branches (veins 6-4) *viz.,* (M1-M3). Veins 3- 2 are the Cubital veins termed Cu1a and Cu1b. Only one Anal vein is present *viz.,* 1A. There is a small spur near the base of 8 th vein, projecting towards the costa called Humeral vein (Plate I. Fig. 1).

External genitalia- Male: (Plate II. Fig. 1). Uncus short, blunt. Socii present. Gnathos composed of two spiral processes, joined apically. Tegumen and Vinculum slender and bar-like. Valve broad in the apical half. Apical and outer margins bordered by a setosed and sclerotised band. Cucullus slightly curved and sclerotised. Costal margin slightly concave. Harpe spatulate, having a broad apex with a tapering proximal part. Juxta with acute lateral lobes. Sacculus straight. Saccus short, U-shaped. Phallus long, stout bow-shaped and curved in the middle. Apex broadened with flat edge. Vesica prominent, extending the entire apex.

Female: (Plate II, Fig. 2). Ovipositor lobes oval, short and fringed with short hairs. Apophysis more or less similar in size. Sinus vaginalis, broad. Ductus short and narrow. Corpus bursae elongate oval, proximally narrowed. Signum prominent, sickle-shaped and swollen in the middle.

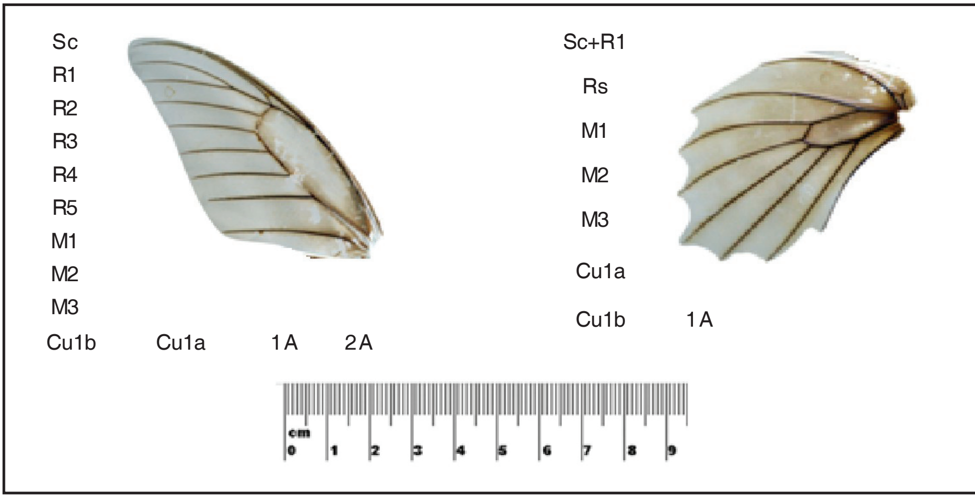

Plate I. Fig. 1 Wing venation of *P. polymnestor* Cramer

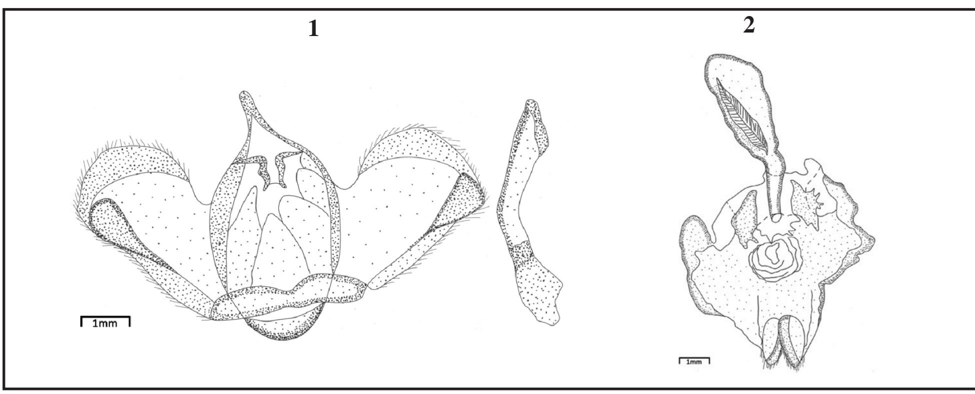

Plate II- Figs. 1 and 2: Male and female genitalia of *Papilio polymnestor*

Biology: Biology of this species, studied by rearing it on *Citrus grandis,* gave an account of the immature stages along with developmental periods is presented below (Plate III, Figs. a - i).

Egg: The eggs are laid singly on the underside of leaves of the host plant. It is pale creamy yellow with a finely roughened surface and is nearly spherical having a diameter of about 1.8 mm. Mean incubation period is 4.43 (± 0.53) days.

Larva: The duration of various instars is presented in Table 1. Detailed description of each instar is given below.

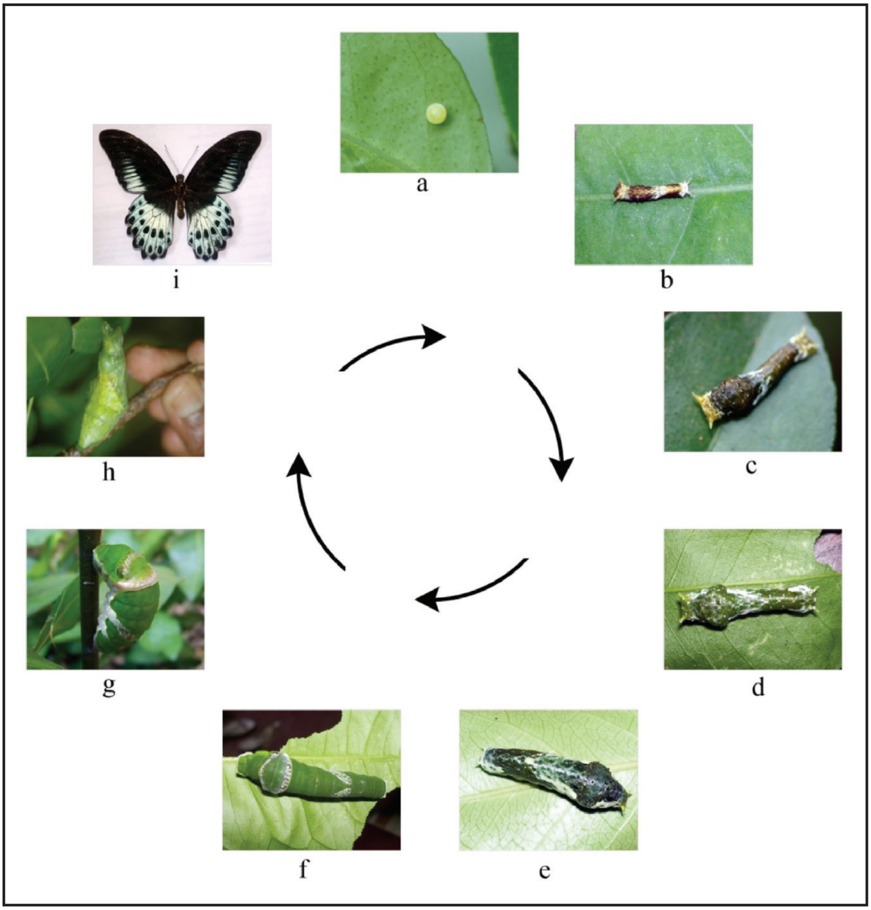

Plate III- (Figs. a - i): Life stages *of P. polymnestor*

Table 1. A comparison of larval instars of *Papilio polymnestor*

Stage	Length (mm)			Width (mm)		
	Range (mm)	Mean (mm)	SD	Range (mm)	Mean (mm)	SD
First instar	5-6	5.7	0.48	-	0.50	-
Second instar	17-19	18	0.67	5-7	6.1	0.57
Third instar	24-26	24.7	0.68	8-9	8.2	0.42
Fourth instar	32-35	33	1.05	9-10	9.5	0.53
Fifth instar	43-45	44	0.94	12-13	12.2	0.42

SD- Standard deviation

Table 2. Duration of various stages of *Papilio polymnestor*

Developmental stage	n	Range (days)	Mean (days)	SD
Egg	10	4-5	4.43	0.53
Larva	10	21-24	22.22	0.97
Pupa	10	18-23	20.78	1.56
Duration (egg – adult)	10	40-46	43	1.80

SD- Standard deviation

First instar larva: It measures about 5.7 (± 0.48) mm in length and 0.5 mm in width. The freshly emerged larva is transparent, greyish white dorsally and dark brown laterally with faint whitish markings on the body. Gradually the whitish dorsal patches change to greenish brown with clear white markings on the prothorax and posterior abdominal segments. After about 3 days, the larva moults to the next instar.

Second instar larva: The larva measures 18 (± 0.67) mm in length and 6.1 (± 0.57) mm in width and the larval duration lasts for 3 days. Body is bright greenish yellow with distinct white markings on the anterior, middle and posterior body segments.

Third instar larva: The larva grows upto a maximum of 24.7 (±0.68) mm in length and 8.2 (± 0.42) mm in width. There is no drastic change in physical appearance except that the larva is more green in colour.

Fourth instar larva: The larva measures 27 mm in length and 9.5 (± 0.53) mm in width. As the growth proceeds, light to dark green coloured cryptic markings mixed with white streaks of the body become prominent.

Fifth instar larva: The larva attains a maximum of 44 (± 0.94) mm in length and 12.2 (± 0.42) mm in width. The larva is bright green in colour with two eye spots on the third thoracic segment, a transverse band at the abdominal segments 1 and 2 and oblique bars on the mid-abdominal segments. The eye spots on the 3rd thoracic segment are connected by a transverse green dorsal band. A similar band occurs between the abdominal segments 1 and 2, with pale bluish gaps between the markings. There are oblique bars extending from the base of abdominal segment 3 to segment 4 one on each side. The second oblique bar occurs at the two sides of abdominal segment 5, wide at the base and tapering to the dorsum. Both sets of oblique bars are mainly whitish dotted with tiny greenish and bluish spots. Pale rose coloured osmeterium is also present just behind its head.

Pupa: Pupa is greenish in colour with large yellowish markings. It bears cephalic horns and is humped in the thoracic area. The pupa measures 37-38 mm in length.

Duration of life cycle: The life cycle is completed within 43 (± 1.80) days under laboratory conditions. The duration of various stages is given in Table 2.

Papilio polymnestor, which is generally found in different habitats including homesteads thrives well in Kerala, on account of the fact that most of its larval host plants are commonly found in our surroundings including wild, ornamental and cultivated plants.

ACKNOWLEDGEMENT

This study formed part of the Ph. D. research work of the first author, with financial support from the Kerala State Council for Science, Technology and Environment.

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(Received 15.05.2014; accepted 15.08.2014)

Entomon 38(1): 27-38 (2013)
Article No. ent. 38103

Characterization of heat shock protein in red flour beetle *Tribolium castaneum* Herbst. (Coleoptera: Tenebrionidae)

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ABSTRACT: Red flour beetle, *Tribolium castaneum* Herbst. (Coleoptera: Tenebrionidae) tolerate the heat treatment in the food processing facilities and storage godowns. The anhydrobiotic character to tolerate the heat treatment of the insect is due to some special metabolites. Characterization of the insect homogenate showed that protein was one of the major constituent imparting the heat tolerance. Using SDS-PAGE (10%) analysis we could decipher the protein with molecular weight of the 70KDa (heat shock protein) act as molecular chaperone in protecting the normal protein in cells of the heat tolerant stages of the beetle. The identity of the heat shock protein (HSP) has been confirmed by the N-terminal sequencing. Further theoretical analysis of the protein sequence shows that the protein is stable and composed of four conserved domains.
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KEYWORDS: Red flour beetle, *Tribolium castaneum*, heat shock protein (HSP), molecular chaperone, N-terminal sequencing.

INTRODUCTION

Red flour beetle (RFB), *Tribolium castaneum* Herbst. (Tenebrionidae:Coleoptera) also known as “bran bug” is one of the serious storage insect pests that originates from infested grains,

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or from dry stored food products, particularly, cereal products such as flours, cake mix, cornmeal's, crackers, dry pet foods and so forth. Other frequently infested items are chocolates, nuts and seeds. Both adult beetles and small white grubs are found in the infested food items. The adult beetles often wander away from the infested materials and are found inside cupboards, or anywhere in the house.

Insecticide sprays are not recommended for managing the RFB in stored food cup boards. Washing shelves with detergent, bleach, ammonia or disinfectants will not have any effect on the pest. Moreover, recent concern over ozone depleting ability of methyl bromide has renewed the interest in exploring heat treatment as potential methyl bromide alternatives (Makhijani and Gurney, 1995). But resistance to killing by extreme heat increases dramatically when the whole insect or cultured cells are pre treated. This increased resistance also known as induced thermo tolerance, which induces synthesis of a set of proteins called heat shock proteins (HSP) (Sanchez and Lindquist, 1990; Nover, 1991; Sanchez *et al*.,1999). The ability of RFB to tolerate the temperature treatments prompted us to characterize the heat shock protein of their system.

Heat shock proteins commonly confer thermal tolerance in all living organisms and can indicate the level of tolerance to heat treatments (Feder and Hoffman,1999). The 70KDa classes of heat shock proteins, which are true heat shock proteins, protect individuals from thermal stress (Pelham, 1986; Lindquist, 1986). The expression of hsp70 gene of *T. castaneum* was heat inducible at various developmental stages (Mahroof *et al*., 2005a). HSP83 protein was involved in protection against thermal stress in newly hatched and matured beetles but in the ovary, HSP83 was only expressed in the follicle cells of mature beetles and not in newly hatched beetles, regardless if the beetles were subjected to heat shock or not (Xu *et al*., 2010). Another class of heat shock protein, HSP90 was expressed in all developmental stages of *T. castaneum* and highly expressed in early pupal and late adult stages (Zhang *et al*., 2013).

MATERIALS AND METHOD

Rearing of the test insect

Red flour beetles were reared on semolina. Food grade plastic insect culture jars sterilized with formalin (2%) were used for rearing the insect. The insect feed (semolina) was partially sterilized in hot air oven (at 70°C for 15 minutes). The culture jars were filled up with semolina (25 g) and five pairs of adult insects were released into each of the containers. Sub-culturing was done at regular intervals.

Level of heat tolerance in different stages of the test insect

The level of heat tolerance of the insect was studied by exposing the different stages of the insect *viz*., neonates, grub, pupa and the adult beetles of *T. castaneum* to different temperature regimes varying from 35°C to 60°C at an incremental increase of 5°C for 4 h. The temperature

ranges were selected on account of the prevailing temperature conditions of storage facilities in India. The time was selected to study the complete mortality of the insect exposed to a particular temperature.

Concentration of samples by Millipore centricon

Various growth stages *viz.*, neonates (1 day old), fifth instar grub (19 days old), pupa (3 days old) and adult beetles (3 days old) of *Tribolium castaneum* were exposed to different temperature regimes varying from 35°C to 60°C at an incremental increase of 5°C for 4 h. A control treatment was maintained where the insects were maintained at ambience. From each treatment 1 g of RFB was sampled out and ground with 1 ml of 0.2 M phosphate buffer (pH 7.0). The extract was then concentrated to 100 µl using 0.22 µm millipore centricon (Kumar *et al*., 2001). The extract required to be concentrated was added to sample reservoir (1 ml) and then it was inserted into the filtrate vial. Spinning was done at the rate of 4000 rpm at 4°C until desired concentration was achieved. For the purpose of filtration the filtrate was reversed back and after the concentration process was completed, the filtrate was discarded. The retentate vial was placed over the sample reservoir and the unit was inverted to recover the retentate. Centrifugation was done at the same speed to transfer the concentrate into retentate vial.

Blotting

Blotting was performed to excise the more concentrated and purified bands from the blot membrane for sequencing purpose. The protein samples were run on SDS-PAGE (10%) gel along with broad range molecular weight marker. After completing the gel run, the gel was transferred into a Trans blot system (Bio Rad) using tank buffer for blotting. This was employed for transferring protein from the SDS gel to poly vinyl difluoride (PVDF) membrane in which the separated proteins were electroblotted onto PVDF membrane (0.2 µm; Bio Rad, Hercules, CA) in presence of methanol (40 % v/v), Tris buffer, (25 mM at pH 8.2) and glycine (190 mM) at 200 mA for 1h using Mini Trans Blot cell (Bio Rad, Hercules,CA) (Kumar *et al*., 2001). Blotting was done under constant current of 200 mA for 1 h at 4°C.

N-terminal sequencing of proteins

In order to excise the specific bands from the blot membrane with greater purity, the test insect protein sample was run on a SDS-PAGE gel and the gel was then transferred onto a sequiblot PVDF membrane (0.2 µm) using the CAPS (3-[Cyclohexyl amino] – 1 propane sulfonic acid) transfer buffer (10 mM CAPS + 10 % methanol, pH 11.0) from Bio Rad at 200 mA for 1 h. After the transfer was completed, the membrane was stained with a staining agent, Coomassie brilliant blue in methanol (50 %) and de-stained 1-3 times in acetic acid (5 %) followed by several washes in de-ionized water. The specific protein bands (70 KDa) were cut out from blotted membrane and were processed for N-terminal protein sequence analysis which is based on Edman chemistry (cleaving reaction of peptides) followed by PTH

(phenylthiohydantoin – a standard amino acid derivative) analysis using microbore HPLC (HP G-1000A equipped with a 1090 PTH analyzer) (Matsudaira, 1993).

Sequence analysis

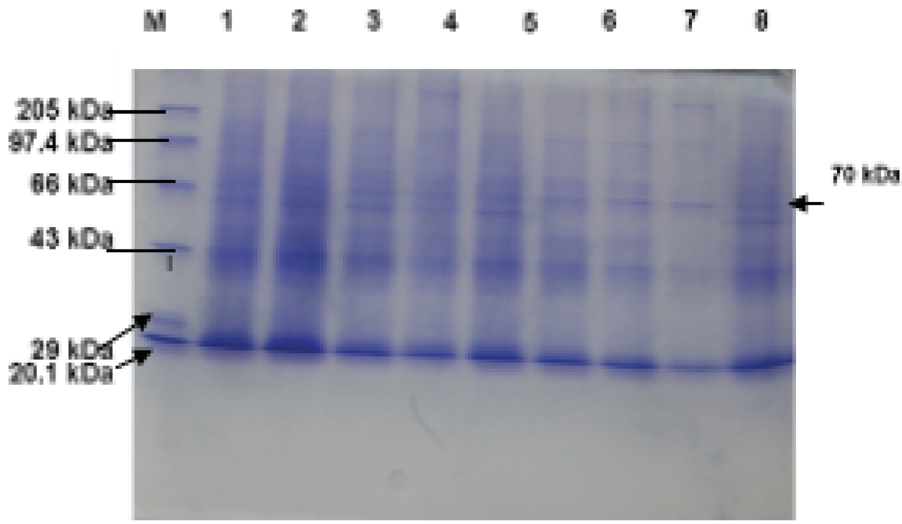
The protein sequence 'Trib hsp' was compared with the sequence available in the database using BLAST tool offered by **National Center for Biotechnology Information (NCBI)**. Protein blast (blast p) was carried out for homology search. The BLAST (Altschul *et al*., 1990) programme 'blast p' provided by NCBI (www.ncbi.nlm.nih.gov/Blast/Blast.cgi) was utilized for the purpose. The primary and the secondary structure of the protein were determined by using the protparam tool and sopma tool. Rasmol and Swiss PDB viewer were used to determine the tertiary structure of the protein.

RESULTS AND DISCUSSION

Determination of molecular weight of the heat shock protein by SDS-PAGE

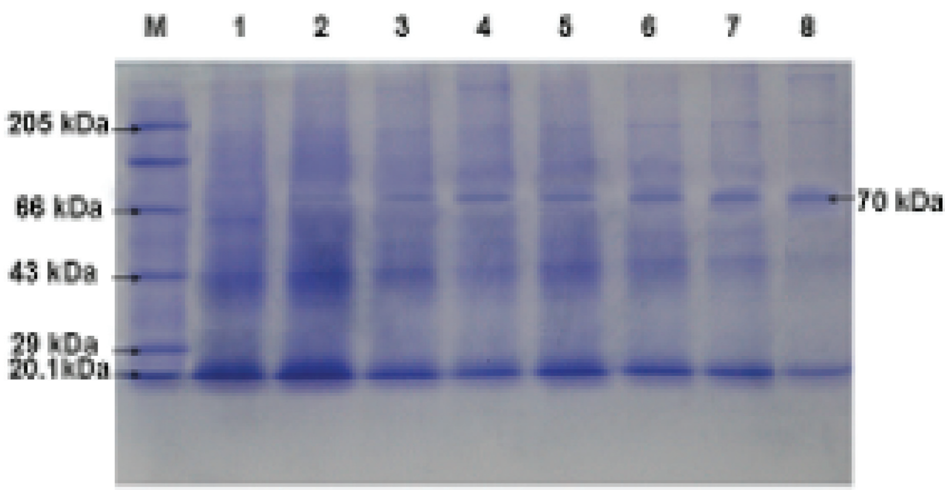
SDS-PAGE for proteins was carried out to characterize the heat shock protein. A very clear band was obtained in the insect samples (subjected to different temperature at 4 h exposure time) as compared to the unexposed insect samples. The SDS-PAGE gel for proteins isolated from the neonate, V instar grub, pupa and adult under stress showed an extra band in all the lanes as compared to the control protein sample that was isolated at room temperature (Fig 1, 2, 3 and 4). The molecular weight of the band was determined using the alpha imager software and it was found out to be 70KDa. The 70KDa protein band got resolved clearly on the SDS-PAGE gel after staining with Coomassie brilliant blue R 250 staining reagent. The Rf value was found to be 0.362 by point to point fit. The Rf value was determined by the ratio of the distance moved by the solvent to the distance moved by the solution. The SDS-PAGE also confirmed 95 per cent purification of the hsp70 due to the appearance of a single band on the gel when 10 µl of sample containing 12 µg of protein was loaded into the wells. Blotting was performed to excise the band with greater purity for N-terminal sequencing. Although hsp70 antibody is commercially available, still specific HSP70 antibody for group of organisms belonging to class hexapoda is yet to be commercialized. Hence, the experiment was performed with the sequencing of the band excised from the blot. The members of the 70 KDa families of stress proteins were produced through the rapid induction during exposure of cells to heat in case of *Drosophila* (Tissieres *et al*. 1974). The SDS-PAGE also confirmed 95 per cent purification of the hsp70 due to the fine resolution of the bands on the gel and it was in conformation with the study done in *Drosophila* (Parsell and Lindquist, 1994). Through this work, the difference in the level of expression of Hsp70 under seven different temperatures tested were studied.

N-terminal sequencing: The N-terminal sequence (Tyr Trp Pro Glu Ala Pro Trp Trp Trp Trp) displayed all the ten amino acids present in the N- terminal region of the protein. Though it is a short sequence, it is enough to confirm the target protein Hsp 70. Total ten residues were obtained using N-terminal sequencing. The 'Trib hsp' was confirmed as the HSP70 produced



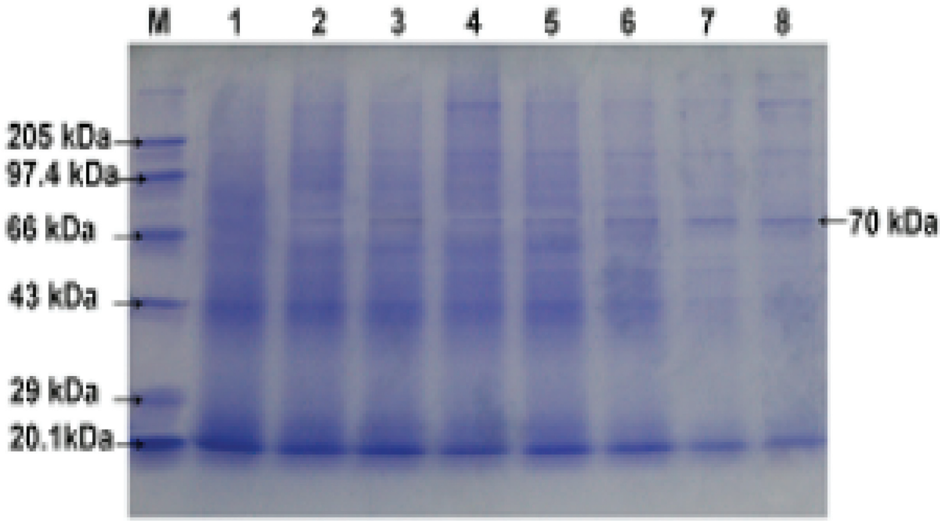
Lane M: Marker protein; Lane 1: Control; Lane 2 to 8: Protein isolated at different temperatures: 2 - 35ºC; 3 - 40ºC (10µl); 4 - 45ºC; 5 - 50ºC; 6 - 55ºC; 7 - 60ºC; 8 - 40ºC (15µl)

Fig 1. SDS-PAGE of *Tribolium castaneum* neonate homogenate under heat stress at different levels



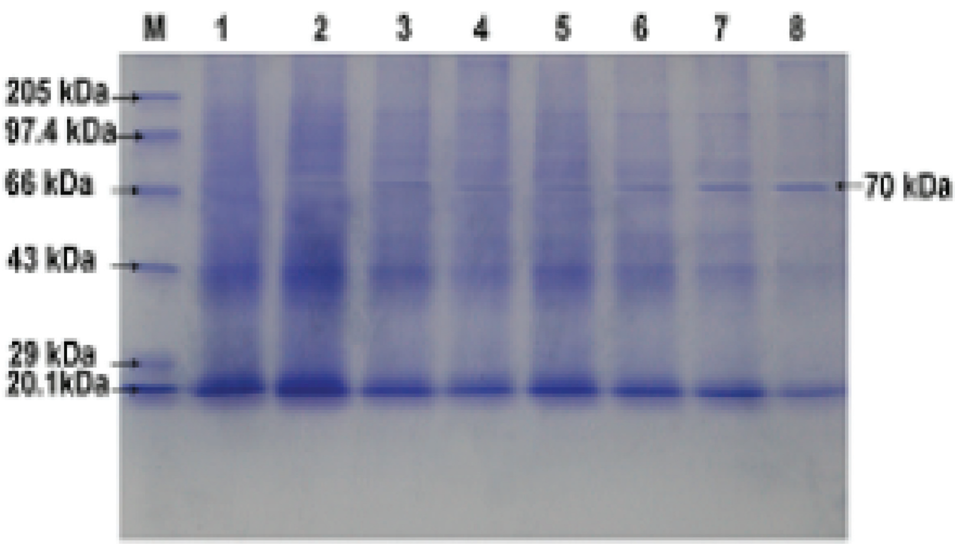
Lane M: Marker protein; Lane 1: Control; Lane 2 to 8: Protein isolated at different temperatures: 2 - 35ºC; 3 - 40ºC (10µl); 4 - 45ºC; 5 - 50ºC; 6 - 55ºC; 7 - 60ºC; 8 - 40ºC (15µl)

Fig 2. SDS-PAGE of *Tribolium castaneum* V-instar grub homogenate under heat stress at different levels



Lane M: Marker protein; Lane 1: Control; Lane 2 to 8: Protein isolated at different temperatures: 2 - 35ºC; 3 - 40ºC (10µl); 4 - 45ºC; 5 - 50ºC; 6 - 55ºC; 7 - 60ºC; 8 - 40ºC (15µl)

Fig 4. SDS-PAGE of *Tribolium castaneum* adult homogenate under heat stress at different levels



Lane M: Marker protein; Lane 1: Control; Lane 2 to 8: Protein isolated at different temperatures: 2 - 35ºC; 3 - 40ºC (10µl); 4 - 45ºC; 5 - 50ºC; 6 - 55ºC; 7 - 60ºC; 8 - 40ºC (15µl)

Fig 4. SDS-PAGE of *Tribolium castaneum* adult homogenate under heat stress at different levels

in the red flour beetle under heat stress as per the sequencing data generated from the N-terminal sequencing for proteins followed by the bioinformatics analysis. Sodium dodecyl sulfate – poly acrylamide gel electrophoresis (SDS-PAGE), combined with electro-blotting and automated Edman degradation, was routinely used for protein purification and N-terminal amino acid sequence analysis (Vandekerckhove *et al*.,1985). It was in accordance with a study done in egg avidin protein of chicken (Kumar *et al*., 2001).

Theoretical analysis of sequence data

Homology of the sequence 'Trib hsp' obtained from the protein product of *T. castaneum* with the other reported sequence was analyzed. The sequence (Fig 5) showed significant homology to red flour beetle (*T. castaneum*) protein sequence deposited in the public domain database using 'blast p' search tool. The blast results showed 98 per cent query coverage and 80 per cent identity to *T. castaneum* heat shock protein.

Primary structure prediction

The physico-chemical properties of the protein with respect to the amino acid composition (Table 1), instability index and grand average of hydropathicity (GRAVY) indicating the solubility of the proteins was determined by using the 'protparam' tool. The molecular weight of the protein was found out to be 70KDa from the protparam results. Further the number of amino acids in the 'Trib hsp' was found out to be 620 with a theoretical isoelectric point of 8.62. The total number of negatively charged residues (Asp + Glu) was 80 while the total number of positively charged residues (Arg + Lys) was 89. Due to a low instability index (27.67), the protein was confirmed to be a stable protein. The negative GRAVY index (-0.36) suggested that the protein was hydrophilic. The primary structure of hsp70 was in confirmation with the study done by in *Drosophila* (Horton and Nakai, 1997) with respect to the stability of the protein. Hsp70 multi gene family was also identified and characterized in *Caenorhabditis elegans* which served as the basis for genetic characterization of a multi cellular eukaryote (Heschel and Baillie, 1990).

Secondary structure prediction

The per cent alpha helices (34.25) and the beta turns (5.82) of the 'Trib hsp' sequence constitute the protein secondary structure (Table 2). Further the per cent of the alpha helices,beta turns and random coils has been depicted by the graphical representation using the 'SOPMA' tool (Fig 6). A similar observation with respect to the secondary structure of the hsp70 in *Drosophila* was also done (Horton and Nakai, 1997).

Tertiary structure prediction

The tertiary structure was visualized using the 'Rasmol' tool and the Ramachandran plot was drawn from the tertiary structure data. The tertiary structure of the HSP70 protein used for homology-based modeling showed the coiling of the alpha helices and beta strands (Fig 7).

Table 1. Amino acid composition of the predicted heat shock protein sequence ('Trib hsp') in *Tribolium castaneum* homogenate

Amino acid			Molar percent of amino acids (Mol %) hsp
Non polar		Gly	4.0
		Ala	7.7
		Val	8.2
		Leu	5.2
		Ile	4.8
		Met	2.6
		Pro	5.8
		Phe	6.8
		Trp	1.1
Polar	Uncharged	Ser	5.6
		Thr	5.6
		Cys	2.3
		Tyr	4.0
		Asn	4.8
		Gln	2.3
	Basic	Lys	12.1
		Arg	2.3
		His	1.8
	Acidic	Asp	5.8
		Glu	7.1

Table 2. Secondary structures present in the 'Trib hsp' in *Tribolium castaneum*

Secondary structures	Composition (%)
Alpha helix	34.25
3_{10} helix	0.00
Pi helix	0.00
Beta bridge	0.00
Extended strand	21.49
Beta turn	5.82
Bend region	0.00
Random coil	38.45
Ambiguous states	0.00
Other states	0.00

The Ramachandran plot (Fig 8) indicated that only two amino acids lie in the disallowed region (red) while rest of the amino acids lie in the allowed region (yellow). From the 'SAVS' result (Ramachandran plot), it was further concluded that 89.5 per cent of the amino acid residues lies in the core region, 10.5 per cent in the allowed region and none in the disallowed region thus indicating the reliability of the structure (Table 3). Similar results were obtained by identifying the sequence similarity between different types of heat shock proteins (Rassov *et*

Table 3. Allowed and disallowed regions in the tertiary structure of the 'Trib hsp' in *Tribolium castaneum*

Plot statistics	Composition (%)
Residues in most favored regions	89.5
Residues in additional allowed regions	10.5
Residues in generously allowed regions	0.0
Residues in disallowed regions	0.0

N-TERMINAL SEQUENCE OUTPUT YWPEAPWWWW:

>gi|91094485|ref|XP_970942.1| PREDICTED: similar to CG9302 -PA [*Tribolium castaneum*]

MKHFNTIFFLLLAFEINIYLTKDTKNAVVDNIYDIKEFKKLIRTKTNVLVCYTNSIKQASQVIKVFRE
AADVIKGQGTMVVMDCSGEAKKVCKKLKVTPDPFIFKHYKNGEFNRDYD RKFTVSSMVNFMRD
PTGDLPWEEDASASDIVHVPDAETLAKFIRQESRPLMVMFYAPWCGFCKTLKPEYVAAAKELKGH
SVLAAIDVNKPENAVIRTLYNITGFPTLLYYKNGAMKFQYEGDNKRQAIVNFMKNPSKPVKVKEQ
EWSEVDSEVVHLTTTNFDPVVKEEASLLVMFYAPWCGHCKKIKPEYEKAAAKLKSDGIPGMMAA
VDATKEVSIADRFSVKGYPTMKYFTYGEHKFDINLREATKIVEFMKNP KEPPPPPPPEKPWSEEESS
VVHLNEENFKSFLKKKRHALVIFYAPWCGHCKKAKPEFTKAAEFFKDDPKVEFAAVDCTTYQGV
CSAHEVSGYPTIKYFSYLNKVVKAYNSGRTADDFIAFMSDPEGNGSSQKTIVPQLTDANFEEEISSK
SAVLVMFYAPWCKQCKEIKPEYQKATNELKQDGFIQLASVDCSSNPVVTDKYDIGTFPTFKLFLN
GKFAADFTGKSTKDDIKSFVVDVKNRKNKEL

Fig 5. Protein sequence from NCBI database with which the hit was obtained

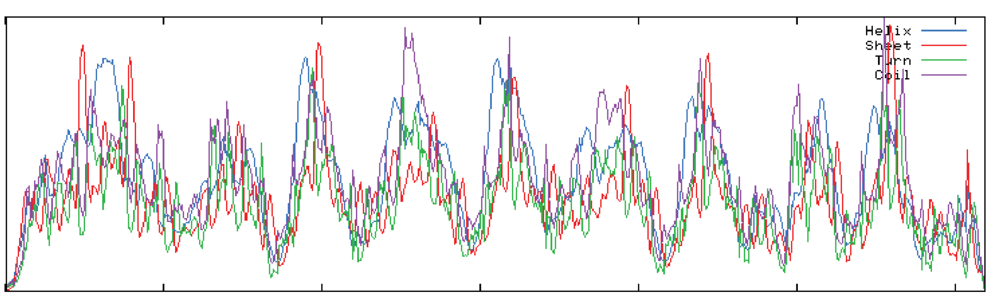


Fig 6. SOPMA result indicating the per cent alpha helices and beta turns

Fig 7. Tertiary structure prediction (Rasmol)

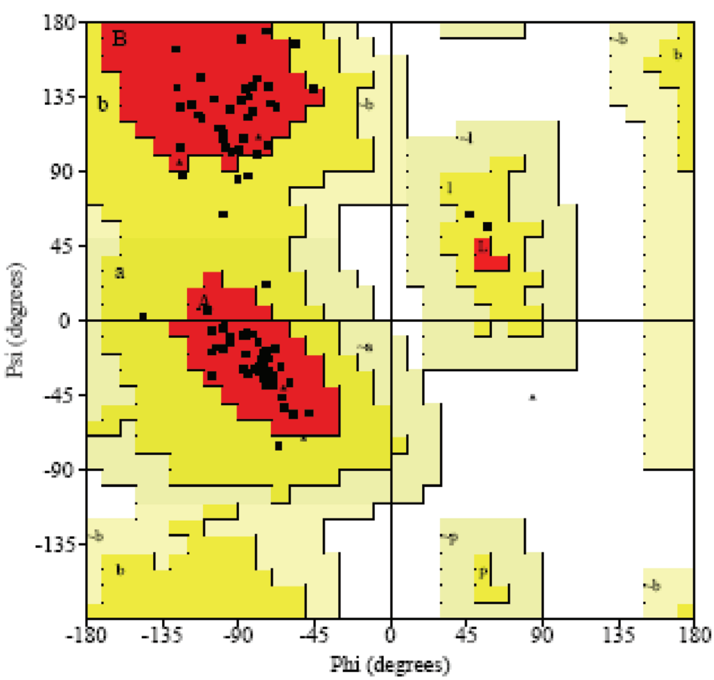


Fig 8. Ramachandran plot model

al., 1995).As temperature increases the pH and ion concentrations are altered, and there are also dramatic effects on macromolecules such as proteins, DNA, RNA, lipids, and carbohydrates, and on cellular structures such as cell and nuclear membranes, mitochondria and ribosomes. Though different classes of heat shock proteins are found in *T. castaneum* when they are subjected to conditions of heat stress, HSP70 is the most dominant heat shock protein found in the early instars that helps this pest to overcome unfavorable conditions (Mahroof *et al*., 2005b). However, HSP70 is found to synthesize at all stages of development in *T. castaneum* in our study. Newly synthesized proteins are shepherded to their correct native structure by these molecular chaperones during heat stress. The HSP70 helps the insect in preventing the aggregation of the already degraded proteins thereby protecting the beetle from progressive cell damage and death during stress.

ACKNOWLEDGEMENTS

We are thankful to the Department of Biotechnology and Centre for Plant Biotechnology and Molecular Biology, College of Horticulture, Kerala Agricultural University for funding of the following project. Our esteemed regards to Dr. P.A. Nazeem and Dr. D. Girija of Centre for Plant Biotechnology and Molecular Biology, College of Horticulture, Kerala Agricultural University for their support in the work. We are thankful to Dr. Pradeep G. Kumar, Scientist F., Rajiv Gandhi Centre for Biotechnology for his timely help during the project.

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(Received 12.03.2014; accepted 14.08.2014)

ENTOMON 38(1): 39-46 (2013)
Article No. ent. 38104

On the occurrence of *Carpophilus maculatus* Murray from Kolkata, India (Coleoptera: Nitidulidae)

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ABSTRACT: *Carpophilus maculatus* Murray, 1864, hitherto recorded from Central America, Pacific Islands, Australia, Southeast Asian Islands, Japan, Hongkong and China has currently been found from Kolkata, India. This species is redescribed and compared with the closely related ones.
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KEYWORDS: Coleoptera, Nitidulidae, *Carpophilus maculatus*, West Bengal, India, new record, redescription.

INTRODUCTION

Extensive exploration often reveals many interesting distributional records of the taxa of sap beetles. Recently, *Carpophilus maculatus* Murray found mainly in the Pacific Islands, Australia, Philippines and Indonesia was intercepted in the food bait trap in Kolkata. Brown (2012) cited distribution of *C. maculatus* outside Australian Region in the Philippines, Indonesia and the Nicobar Islands (India). The species is now being recorded from the Indian mainland. Earlier, Murray (1864) described the species *Carpophilus maculatus* from Oahu, the Hawaiian Islands. Subsequently, Sharp (1878) while dealing with the Hawaiian Nitidulidae presumed *Carpophilus vittiger* Murray to be closely related to *C. maculatus* and stated 'widely distributed in Malay Archipelago and India'. Later, Grouvelle (1908 and 1913) did not show any record of *C. maculatus* Murray and *C. vittiger* Murray [a synonym of *C. dimidiatus* Fabricius *sensu* Grouvelle] from India. No material record of *C. vittiger* Murray is also traced from India. Leschen & Marris (2005) recorded *C. maculatus* Murray from Kermadec Islands, New Zealand, synonymized *C. vittiger* Murray with this species and cited geographical distribution of the

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species. Jélinek & Audisio (2007) in Palaearctic Catalogue reported *C. maculatus* from China, Hongkong, Japan, Australian and Oriental Regions. Brown (2009) considered *C. maculatus* sensu Leschen & Marris (2005) from Kermadec Island to be *C. oculatus* Murray. The species is characterized, compared with the related species, and its current distribution noted herein. The materials are deposited in the collection of the Zoological Survey of India (ZSIC).

MATERIALS AND METHOD

The specimens were collected from food bait bottle trap set in a garden at Garia, Kolkata (22.466531 °N, 88.383014 °E). The bottle trap (Fig. 1) was made by taking a disposed 2-litre volume plastic pet bottle. The bottle cap was taken off. A horizontal incision was made on the bottle using a sharp blade at about two inches below the bottle neck. The entire neck area was chopped off from the bottle and kept aside. Then, a small transparent, cylindrical, plastic container (without lid) was stuck at the base of the bottle at the bottom with glue and cello tape. Food in the form of banana pelts (two in number) and 40 ml of beer was kept in that smaller container and soap water was poured into the rest of the surrounding region in the bottle excluding the smaller container with food and taking special care that the water level stays much below the mouth of the smaller container. The chopped off portion of the bottle was then inverted and re-inserted into the bottle thereby forming a short funnel. The junction of the funnel and the bottle was sealed with tape and two holes were made onto the sides of the plastic bottle to tie a string on either side so that the device could be hanged. The trap was kept hanging from the branch of a tree at a height of 2 metres from the ground in a garden. The scent of beer mimics the scent of fermenting sap which attracts sap beetles (Nitidulidae). Attracted by the scent of beer and fermenting banana pelt, the nitidulid beetles along with other insects enter the trap from the bottle mouth of the funnel. However, there is no route to escape as the beetles cannot fly high enough to reach the bottle mouth and instead falls into the soap water. Flight is further hindered due to the surface tension of the soapy water and the beetles are trapped. The trap was kept in the garden for a period of 48 hours before removing it and collecting the trapped beetles from it with a soft brush and preserved in 70% alcohol. The specimens were mounted on rectangular hard paper board and pinned with proper locality and habitat data. Mounted dry specimens were relaxed by putting in water for about an hour and the abdomen was dissected out by making an incision between metathorax and abdomen under a dissecting microscope. The abdomen was then placed in 10% KOH solution, for about 24 hours and washed in distilled water and mild acetic acid solution for 10 minutes respectively. It was then passed through different grades of alcohol from 30% to 100% for 10 minutes in each grade for complete dehydration and then transferred to clove oil. The abdomen was then placed on a clear glass slide with a drop of clove oil and the male genitalia was dissected out with two fine dissecting needles under a WILD M5A stereoscopic binocular microscope and placed in a drop of Canada balsam on a piece of cover glass. The cover glass was glued on a piece of ivory paper and pinned with the respective specimen with required data for types and other specimens. External features and other structures were studied using Leica ® M205A stereoscopic microscope and images were recorded, when necessary. Illustrations were made with the aid of Camera lucida; detailed features of the aedeagus were

PLATE- I

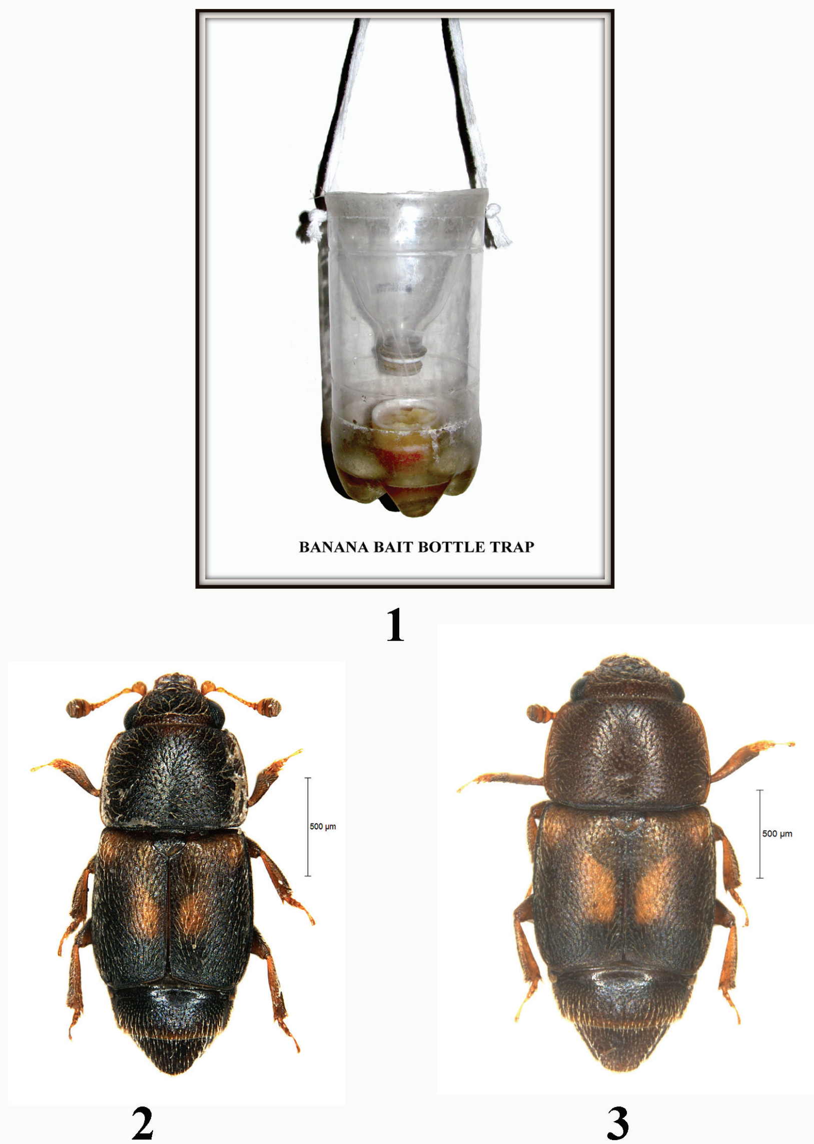


PLATE I. Figs. 1. Banana-Beer Bottle Trap; 2, *Carpophilus maculatus* Murray (male); 3, *C.maculatus* Murray (female)

sketched by using the digitized images and examination under an OLYMPUS compound microscope.

RESULTS AND DISCUSSION

SYSTEMATIC ACCOUNT

Family NITIDULIDAE Latreille, 1807

Subfamily CARPOPHILINAE Erichson, 1843

Genus *Carpophilus* Stephens, 1830

Carpophilus (Myothorax) maculatus **Murray**

Carpophilus maculates Murray, 1864: 372.

Carpophilus vittiger Murray, 1864: 373.

Carpophilus (Myothorax) maculatus: Leschen & Marris, 2005: 15.

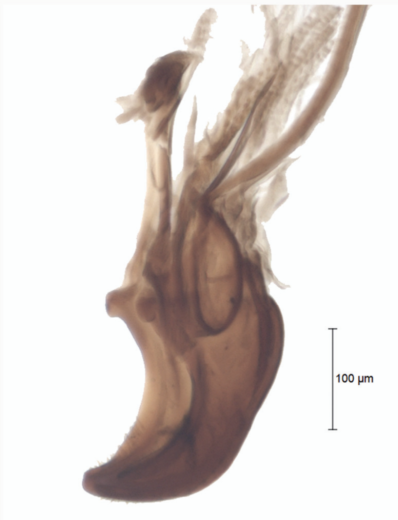
Oblong-ovate, moderately convex, dorsum not unicolorous- head, pronotum and abdomen dark brown to black, pale longitudinal 'T'- shaped patch near the suture and humeral region of the dark brown elytra, suture blackish; cuticle with fine, moderately long, golden, decumbent pubescence; legs and antennae testaceous. Antenna about 1.6x as long as head; antennal club 1.3x as long as broad, rather compact. Prothorax broader than long (1.0: 1.4), nearly quadrangular in shape, front margin almost straight, sides arcuate, hind margin straight with slight sinutation near the scutellum, front angles obtusely rounded, hind angles broadly rounded. Elytra about as long as broad. Legs with tibiae much flattened; tarsi dilated and densely setose. Ventral side darker than dorsum, dark brown and more finely punctate; gular region of head with distinct antennal groove converging posteriorly. Mesosternum devoid of pubescence and median carina. Metasternum with femoral line arising from the mesocoxae forming a small axillary space near the junction of mesocoxae and metepimeron.

Aedeagus with lateral lobes in ventral view (Pl. II Fig. 5,7) broadly elongate, somewhat trowel-shaped, more or less uniformly broad along length, apices convergely bent inward; in lateral view (Pl. II Fig. 4,6) considerably bent, somewhat '**,**' -shaped, gradually narrowed beyond basal third with short setae on borders of lobes near apices.

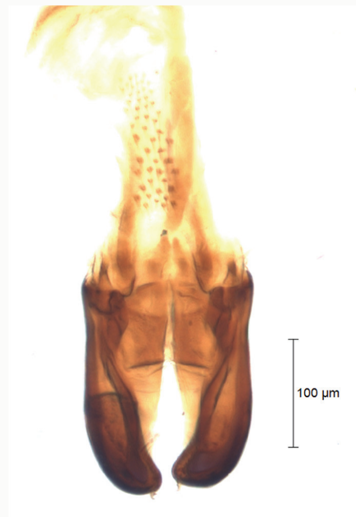
Measurements (mm.): Total length 2.56–3.17, width of head across eyes 0.48–0.61, length of antenna 0.56–0.70, length and width of prothorax 0.67–0.81 and 0.98–1.17, length and width of elytra 0.98–1.19 and 1.05–1.28.

Material examined: 3 ex. INDIA: West Bengal, Kolkata, Garia, (22.466531°N, 88.383014°E), 15.03.2014, J. Dasgupta, *ex.* Banana-beer bottle trap.

PLATE- II



4



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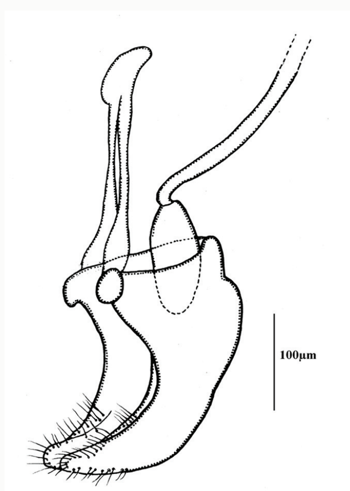

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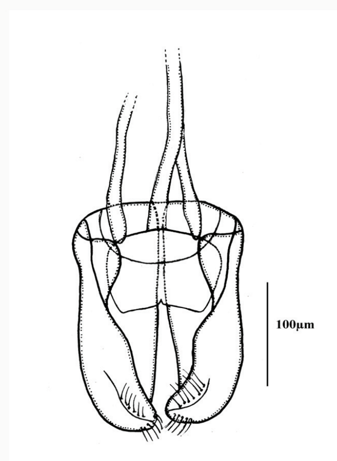

7

PLATE II. Figs. 4-7. Male genitalia of *C. maculatus* Murray ; 4- lateral view- photo; 5- ventral view - photo; 6 - lateral view – drawing and 7 - ventral view -drawing

Distribution: INDIA: West Bengal (New record), Nicobar Islands; Central America [Cuba]; Pacific Islands [Bismarck Archipelago, Caroline Islands, Cook Islands, Easter Island, Fiji, Gilbert Islands, Guam, Hawaii, West Papua, Kiribati, Marquesas Islands, Mariana Islands, Marshall Islands, Nauru, New Caledonia, Niue, Palau, Papua New Guinea, Samoa, Society Islands, Solomon Islands, Tokelau, Tonga, Tuamotu Archipelago, Austral Islands, Tuvalu, Vanuatu, Christmas Island, Cocos-Keeling Islands, Malaku Islands]; New Zealand (?); Australia; Philippines; Indonesia, China, Hongkong, Japan [see Map- I].

Remarks: There was a taxonomic paradox regarding the specific status of this species and *Carpophilus oculatus* Murray. The latter species is also found primarily in the Pacific Islands. *Carpophilus maculatus* can apparently be distinguished from *C. oculatus* Murray by the colour pattern; *C. oculatus* Murray has apex of lateral lobe of aedeagus in lateral view either pointed, re-curved or emarginate *vs*. presence of pale longitudinal or oval patch near the suture and base of each elytron often forming the shape of 'T' and lateral lobes of aedeagus with apex rounded in lateral view in *C. maculatus* Murray. Moreover, there are also differences in punctation and width of pronotal carinae. Though these two species show range of colour variation and occasionally create confusion in species determination by external characters, structure of male genitalia is found to be the reliable basis for species differentiation. Brown *et al.* (2012) resolved the problem and confirmed the separate specific status of these two species using molecular study.

ACKNOWLEDGEMENTS

We are grateful to Dr. K. Venkataraman, Director, Zoological Survey of India (ZSI) for providing necessary facilities to carry out the work. Dr. M.E. Hassan, Scientist, ZSI extended constant support and co-operation in the research work. Following persons extended sincere support in the study: Sri Mukul Maity [Owner of the garden] permitted to carry out field trapping of beetles; Dr. Eyarin Jehamalar, Research Associate, ZSI shared field observations, and Miss Srimoyee Basu, SRF, ZSI helped in preparation of the map in the paper. Dr. S. D. J. Brown, Bio-Protection Research Centre, Lincoln University, Canterbury, New Zealand provided useful literature for the paper. Two anonymous reviewers of the paper have critically gone through it to offer valuable suggestions and pointed out changes for its improvement.

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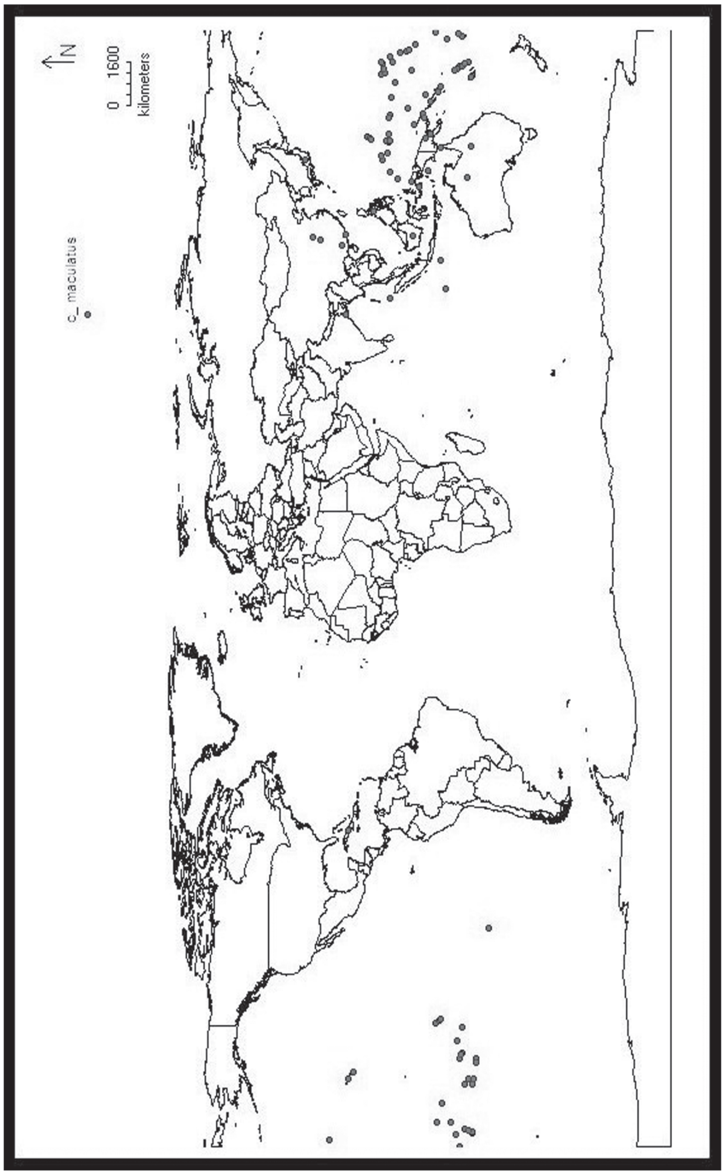
MAP- I



MAP I. Current distribution of *C. maculatus* Murray in the world [marked in dots].

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(Received 12.05.2014; accepted 10.08.2014)

Entomon 38(1): 47-52 (2013)
Short Communication No. ent. 38105

Mite fauna associated with major vegetable crops of Thrissur district, Kerala

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ABSTRACT: A survey was conducted to explore phytophagous and predatory mites associated with six major vegetable crops namely, Brinjal, Bhindi, Amaranthus, Cowpea, chilli and bitter gourd in Thrissur district, Kerala during 2011- 2012. A total of 19 species of mites belonging to eight families in two suborders namely Prostigmata and Mesostigmata were identified. The phytophagous mite families recorded were Tetranychidae, Tenuipalpidae and Tarsonemidae represented by the genera *Tetranychus*, *Eutetranychus*, *Brevipalpus* and *Polyphagotarsonemus. Tetranychus urticae* was found to be the dominant phytophagous mite genus on Brinjal, Bhindi, Amaranthus and Cowpea, where as in Chilli and Bittergourd the tarsonemid mite, *Polyphagotarsonemus latus* (Banks) was the predominant one. The important phytoseiid predators recorded in the study include *Amblyseius paraaerialis* Muma, *Paraphytoseius orientalis* Narayanan, *Neoseiulus longispinosus* (Evans), *Phytoseius* sp., *Euseius macrospatulatus* Gupta, *Typhlodromips* sp. and Scapulaseius sp. © 2013 Association for Advancement of Entomology

KEY WORDS: Mites, Brinjal, bhindi, amaranthus, cowpea, bitter gourd, chilli

Mites are a diverse group which is worldwide in distribution and inhabit all types of habitats. Phytophagous mites are considered to be important pests of crop plants and some are quite injurious causing heavy loss to farmers. Contrary to this, predatory mites help in the natural control of these mite pests to some extent. In India, occurrence of 2350 species of mites belonging to 725 genera under 190 families were reported (Gupta and Gupta, 1999). This forms only a small percentage of the world's known mite fauna. However, information on the diversity

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of phytophagous mites affecting major vegetable crops in Kerala is limited. In this background, the proposed study was made to record important acarine species, both phytophagous and predatory mites associated with major vegetable crops grown in Thrissur district, Kerala.

The work was carried out in the Acarology laboratory of the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2011-2012 to explore the faunal composition of mites associated with six major vegetable crops of Thrissur district, Kerala. Random roving surveys were carried out in the farmers' fields from three vegetable growing tracts namely, Pazhayannur, Kannara and Vellanikkara of Thrissur district to collect phytophagous and predatory mites associated with six vegetable crops *viz.*, brinjal, bhindi, amaranthus, cowpea, bitter gourd and chilli. Mite infested leaf samples (3 leaves per plant) were collected from ten randomly selected plants each of brinjal, bhindi, amaranthus, cowpea, bitter gourd and chilli separately in polythene bags (40cm × 30 cm and 50 µ) from each locality and brought to the laboratory. In the laboratory, the leaves were observed under stereomicroscope and mite specimens were collected using camel hair brush and preserved in 70 per cent ethyl alcohol with a few drops of glycerol taken in glass vials of 1.5ml capacity and labelled.

The mites collected in the survey were mounted in Hoyer's media to prepare permanent slides. Single specimen representing both male and female mites of the same species was mounted separately on different slides. The male tetranychid mites were mounted in the lateral position also to ensure the better orientation of the genital structures which were very important for species determination. The mounted specimens were kept in an oven at 40^{o}C for seven to ten days and dried specimens were then labelled and numbered serially for identification. The permanent slides prepared were observed under phase contrast microscope with image analyzer software to study the taxonomic characters. Identification of the slide mounted mite specimens was made using appropriate literature.

A total of 19 species of phytophagous and predatory mites belonging to eight families were recorded in the study (Table 1). The phytophagous mite families recorded were Tetranychidae, Tenuipalpidae and Tarsonemidae represented by the genera *Tetranychus Eutetranychus, Brevipalpus* and *Polyphagotarsonemus.* The predatory mite families include Phytoseiidae, Stigmaeidae, Cunaxidae, Bdellidae and Tydeidae. The acarine faunal diversity in different vegetable crop environments is detailed below.

Mite fauna in brinjal

Ten species of mites belonging to three phytophagous and seven predatory mites were observed in brinjal. The two spotted spider mite, *Tetranychus urticae* Koch was the predominant phytophagous mite. *Polyphagotarsonemus latus* (Banks) and *Brevipalpus phoenicis* (Geij.) occurred in very minor form. The predatory mite fauna included *Neoseiulus longispinosus* Evans, *Paraphytoseius orientalis* Narayanan. *Amblyseius* sp., *Phytoseius* sp., *Typhlodromips* sp. and *Euseius* sp. all belonging to the family Phytoseiidae and *Agistemus gamblei* Gupta of the family Stigmaeidae.

Table I Mite fauna in major vegetable crops of Thrissur District, Kerala

Host plant	Phytophagous mites		Predatory mites	
	Mite genus/species	Family	Mite genus/species	Family
Brinjal	*Tetranychus urticae* Koch *Polyphagotarsonemus latus* (Banks) *Brevipalpus phoenicis* (Geij.)	Tetranychidae Tarsonemidae Tenuipalpidae	*Paraphytoseius orientalis* Narayanan *Neoseiulus longispinosus* (Evans) *Amblyseius* sp. *Euseius* sp. *Phytoseius* sp. *Typhlodromips* sp. *Agistemus gamblei* Gupta	Phytoseiidae Phytoseiidae Phytoseiidae Phytoseiidae Phytoseiidae Phytoseiidae Stigmaeidae
Bhindi	*T. urticae*	Tetranychidae	*N. longispinosus* *Typhlodromips sp.* *Amblyseius sp.* *Agistemus sp.*	Phytoseiidae Phytoseiidae Phytoseiidae Stigmaeidae
Amaranthus	*Tetranychus sp.* *B. phoenicis*	Tetranychidae Tenuipalpidae	*N. longispinosus* *Amblyseius* sp. *Euseius* sp. *Scapulaseius* sp. *Typhlodromips* sp.	Phytoseiidae Phytoseiidae Phytoseiidae Phytoseiidae Phytoseiidae
Cowpea	*Tetranychus* sp. *Eutetranychus* sp. *P. latus*	Tetranychidae Tetranychidae Tarsonemidae	*N. longispinosus* *Typhlodromips* sp. *Amblyseius* sp1.	Phytoseiidae Phytoseiidae Phytoseiidae
Bitter gourd	*P. latus*	Tarsonemidae	*Typhlodromips* sp. *Euseius macrospatulatus* Gupta	Phytoseiidae Phytoseiidae
Chilli	*P. latus*	Tarsonemidae	*Amblyseius paraaerialis* Muma *Euseius* sp. *Typhlodromips* sp. *Tydeus* sp. *Agistemus* sp. *Cunaxa* sp. *Bdella* sp.	Phytoseiidae Phytoseiidae Phytoseiidae Tydeidae Stigmaeidae Cunaxidae Bdellidae

Mite fauna in bhindi

Of the five species of mites recorded from bhindi, *T. urticae* was the only phytophagous mite. The predatory mites included *N. longispinosus*, *Typhlodromips* sp. and *Amblyseius* sp, of the family Phytoseiidae and *Agistemus* sp. belonging to Stigmaeidae.

Mite fauna in amaranthus

In amaranthus, two species of phytophagous mites recorded were *Tetranychus* sp. and *B. phoenicis* of which *Tetranychus* was the predominant one. Five species of predatory mites recorded include *N. longispinosus*, *Amblyseius* sp., *Euseius* sp., *Scapulaseius* sp. and *Typhlodromips* sp., all belonging to the family Phytoseiidae.

Mite fauna in cowpea

In cowpea, three phytophagous mites and three predatory mites were recorded. The phytophagous mites included *Tetranychus* sp., *Eutetranychus* sp., and *P. latus*. Predatory mites recorded were *N. longispinosus*, *Typhlodromips* sp. and *Amblyseius* sp.

Mite fauna in chilli

P. latus was the only phytophagous mite recorded from chilli. However, seven different species of predatory mites were collected during the study which included *Amblyseius paraaerialis* Muma, *Euseius* sp., *Typhlodromips* sp. of the family Phytoseiidae, *Tydeus* sp. of the family Tydeidae, *Agistemus* sp. of Stigmaeidae, *Cunaxa* sp. belonging to Cunaxidae and *Bdella* sp. of Bdellidae.

Mite fauna in bitter gourd

One phytophagous mite, *P. latus* and two predatory mites namely *Euseius macrospatulatus* Gupta and *Typhlodromips* sp. were recorded in bitter gourd.

Faunal studies of mites in six vegetable crops revealed highest diversity of mites in brinjal with three phytophagous and seven predatory mites and the least diversity in bitter gourd with one phytophagous and three predatory mites. Spider mites belonging to the genus *Tetranychus* were found to be the dominant phytophagous mite in brinjal, bhindi, amaranthus and cowpea whereas, in chilli and bitter gourd, the tarsonemid mite, *Polyphagotarsonemus latus* (Banks) was the predominant species. These mites were reported as important mite pests of vegetable crops from different parts of India (Gupta, 1991; Gulati, 2004; Rai and Indrajeet, 2011). Karmakar (1997) reported the broad mite, *P. latus* as one of the most destructive pests and a major contributing agent of the devastating “Murda” complex in chilli. *Brevipalpus phoenicis* (Geij.) was the only tenuipalpid mite observed during the study and it was reported in amaranthus and brinjal.

The predatory mites found associated with vegetables in the present study belonged to five families *viz*., Phytoseiidae, Stigmaeidae, Tydeidae, Cunaxidae and Bdellidae among which Phytoseiidae predominates. Several species of phytoseiid mites were reported as effective predators of plant feeding mites all over the world in many diverse crop ecosystems (Sadanandan and Ramani, 2006; Karmakar and Gupta, 2010).

Predatory mites *Cunaxa* sp., *Bdella* sp. and *Tydeus* sp. were found in association with *P. latus* in chilli. The Stigmaeid mites of the genus *Agistemus* was found in association with phytophagous mites on brinjal, bhindi and chilli. *Agistemus* spp. has gained a great economic importance as biocontrol agent and play pivotal role in controlling phytophagous mites and soft bodied insects in different vegetables (Khan *et al*., 2008).

Studies have to be conducted to identify the host range and extent of damage caused by the mite pests on vegetable crops. Further, potential of the predatory mites in bringing down the population of phytophagous mites in vegetable fields need to be assessed. This would lead to the identification of potential predatory mite species for utilization in successful biological control programmes.

ACKNOWLEDGEMENT

The authors are thankful to Dr. C. Chinnamade Gowda, Senior Acarologist, All India Network Project on Agricultural Acarology, University of Agricultural Sciences, GKVK, Bangalore for providing appropriate literature for the identification of mite taxa.

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(Received 20.03.2014; accepted 04.08.2014)

ENTOMON 38(1): 53-58 (2013)
Short Communication No. ent. 38106

Incidence of *Erionota thrax* (Hübner) (Lepidoptera: Hesperiidae) as a pest of banana in Kerala

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ABSTRACT: The Palm Redeye *Erionota thrax* (Hübner) (Lepidoptera: Hesperiidae) is reported for the first time as a pest of plantain in Kerala. Of the various cultivars of plantain, it shows preference to the Njalipoovan variety. The life cycle takes about 40 days for completion. Severe incidence of this pest has been noticed in plantain plantations at Palghat, Nilambur and Peechi. Incidence of an unidentified Tachinid parasite infesting the pupal stages of this skipper has been noticed at Peechi. © 2013 Association for Advancement of Entomology

KEYWORDS: Palm Redeye, *Erionota thrax* (Hübner), Banana Skipper, Kerala, India.

The Palm Redeye *Erionota thrax* (Hübner) (Lepidoptera: Hesperiidae), also known as Banana Skipper is a serious defoliator of plantains throughout the South East Asia and Papua New Guinea. In India, it has been reported from Calcutta, Assam and Kolar (Wynter Blyth, 1957); Palani Hills (Ghorpade and Kunte, 2010) and Chattisgarh and Madhya Pradesh (Tipple and Ghorpade, 2012). Occurrence of this pest was reported from Madurai, Theni, Coimbatore and Erode Districts of Tamil Nadu and Chamrajnagar District of Karnataka (Padmanaban, 2014). During September - October 2013, epidemic build up of this pest was noticed in banana plantations at several places in Kerala v*iz.,* Peechi, Palghat and Nilambur. Of the various cultivars of banana, it showed preference to the Njalipoovan variety of plantain causing severe damage. The larvae characteristically feed within rolls of leaves which they make by cutting the leaf sheath transversely. The larvae are voracious feeders and consume the entire foliage leaving only the mid rib (Pl. I, Figs. 1- 4). As the larva grows, the size of roll also

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Fig. 1. Plantain infested by *E. thrax*

Fig. 2. An infested leaf showing rolls made by caterpillars of *E. thrax*

Fig. 3. A close-up of leaf rolls made by caterpillars of *E. thrax*

Fig. 4. Close-up of a leaf roll showing excretory pellets of *E. thrax*

Plate I (Figs. 1-4) Plantain leaf showing infestation by *Erionota thrax*

changes so as to accommodate the growing larva. This is the first record of this skipper as a pest from Kerala.

The adults of *E. thrax* are pale brownish in colour measuring 70-76 mm in wing expanse (Pl. II, Fig. 5). Upper side of the wings is pale brownish. There are three yellowish orange spots in the centre of the upper side of the forewing of which two are more or less equal in size while the other is relatively small. The hind wing does not have any spot. In general colour and wing pattern it bears a close resemblance to the Giant Red eye *Gangara thyrsis* (Fb.) except that in

Fig. 1. Eggs of *E. thrax*

Fig. 2. Young larva of *E. thrax*

Fig. 3. Full grown larva of *E. thrax*

Fig. 4. Pupa of *E. thrax*

Fig. 4. Parasitised pupa of *E. thrax*

Fig. 5. Adult of *E. thrax*

Plate II (Figs. 1- 5) Different stages of *E. thrax*

the latter, there are three large quadrate, semi transparent yellow spots across cell on the fore wing while in the former, of the three yellowish orange spots in the centre of the upper side of the forewing, two are more or less equal in size and the other is relatively small. The apical spots on the forewing and the spots in the middle of the wing are more or less of the same size.

The adults are generally active during the dusk and lay their eggs in groups under the leaf. As many as 25 eggs are laid at a time (Pl. II, Fig. 1). The eggs are round, hyaline, pale reddish, and measures 0.30 mm in size. The eggs hatch in 3 to 4 days and the larvae come out. The larva is white in colour bearing whitish fine bristles (Pl. II, Figs. 2 & 3) which in the case of *G. thyrsis* are feathery / puffy and are mainly seen on the upper surface of the body. Larva takes 20-25 days for attaining maturity. When full grown, the larva undergoes pupation within the leaf roll itself. The pupa is cylindrical in shape and pale yellow in colour. Its anterior end is slightly broad and the posterior end is narrow. Pupal period lasts for 8-10 days. On the whole, the life cycle takes about a month for completion. In banana plantations, because of the availability of optimum conditions, the generations are continuous and overlapping leading to severe epidemics.

During September, 2013, incidence of an unidentified Tachinid (Diptera: Tachinidae) parasite infesting the pupae was noticed at Peechi ((Pl. III, Figs. 1-2). Earlier, Intan Ahmad (2008) has reported eight primary parasitoids on this skipper which included a Tachinid – *Palexorista solensis*. The other parasitoids recorded on this skipper are the Hymenopterans – *Ooencyrtus erionotae* (Encyrtidae), *Pediobius erionotae* (Eulophidae), *Agiommatus sumatraensis* (Pteromalidae), *Cotesia* (*Apanteles*) *erionotae* (Braconidae), *Charops* sp. (Ichneumonidae), *Xanthopimpla gampsura* (Ichneumonidae) and *Brachymeria thracis* (Chalcididae).

Fig. 1. Pupa of an unidentified Tachinid parasite reared from the pupa of *E. thrax*

Fig. 2. Adult of an unidentified Tachinid parasite reared from the pupa of *E. thrax*

Plate III (Figs. 1-2) Pupal parasite of *E. thrax*

Several studies have been made on the control of the insect using insecticides (Waterhouse and Norris, 1989; Waterhouse *et al.,* 1998) and by biological control agents such as *Ooencyrtus erionotae* (egg parasite) and *Apanteles erionotae* (Mau *et al.,* 1980; Sands *et al.,* 1993). Application of Nimbecidine has been recommended by the Department of Agriculture, Kerala to control the caterpillars.

ACKNOWLEDGEMENT

We are grateful to our colleague Dr. K. K. Ramachandran (Division of Wildlife Biology) for information on the incidence of this pest and also for the photographs.

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(Received 01.04.2014; accepted 04.08.2014)

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(Form IV, Rule 8 of Registration of Newspapers (Central) Rules 1956)

1.	Place of publication	:	Trivandrum
2.	Periodicity of publication		Quarterly
3.	Printer's name, nationality and address	:	Dr K D Prathapan, Indian, Secretary, Association for Advancement of Entomology, Department of Entomology, College of Agriculture, Kerala Agricultural University, Vellayani PO, Thiruvananthapuram 695522, Kerala, India
4.	Publisher's name, nationality and address	:	- do-
5.	Editor's name, nationality and address	:	Dr M S Palaniswami, Indian, Chief Editor, ENTOMON, Association for Advancement of Entomology, Department of Entomology, College of Agriculture, Kerala Agricultural University, Vellayani PO, Thiruvananthapuram 695522, Kerala, India
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